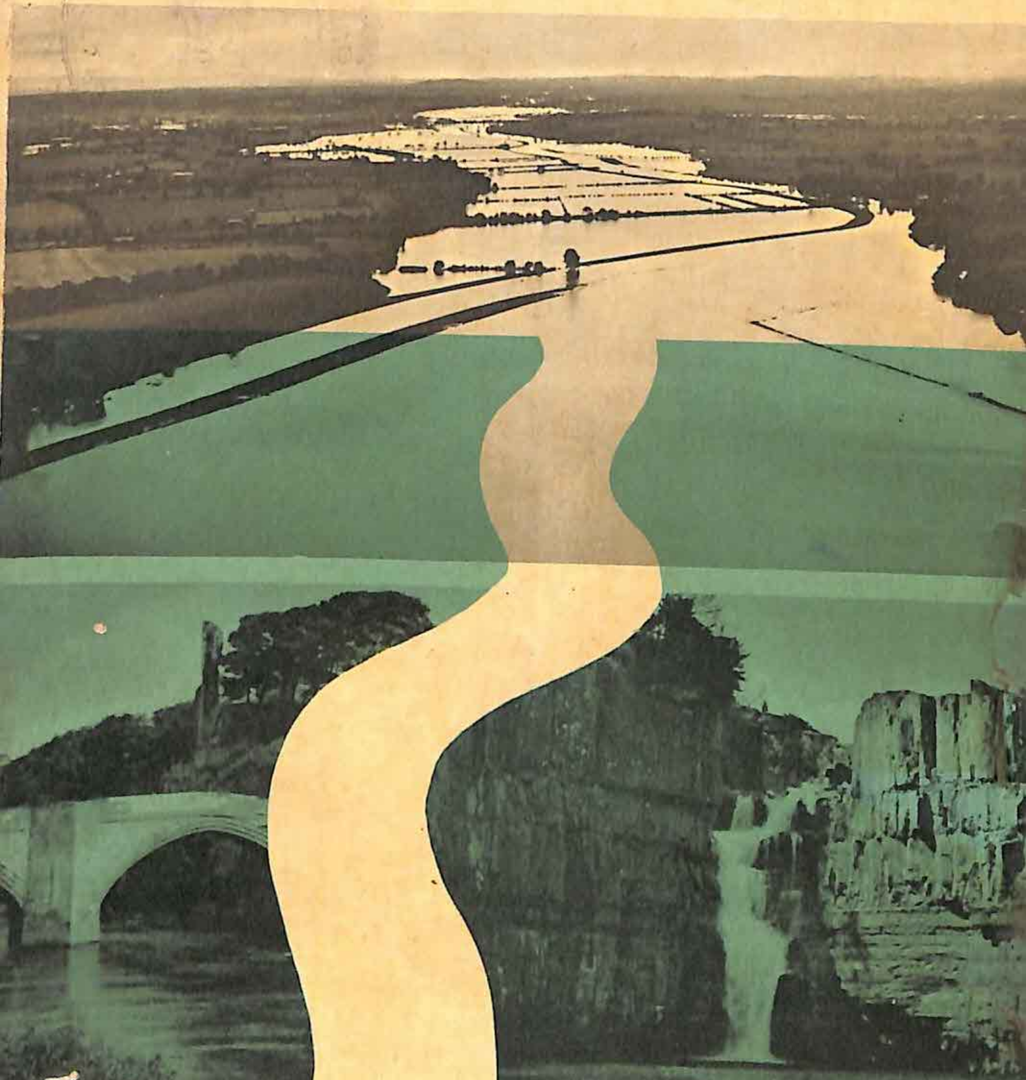
DISCOVERING RIVERS



M. O. GREENWOOD

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Discovering Rivers

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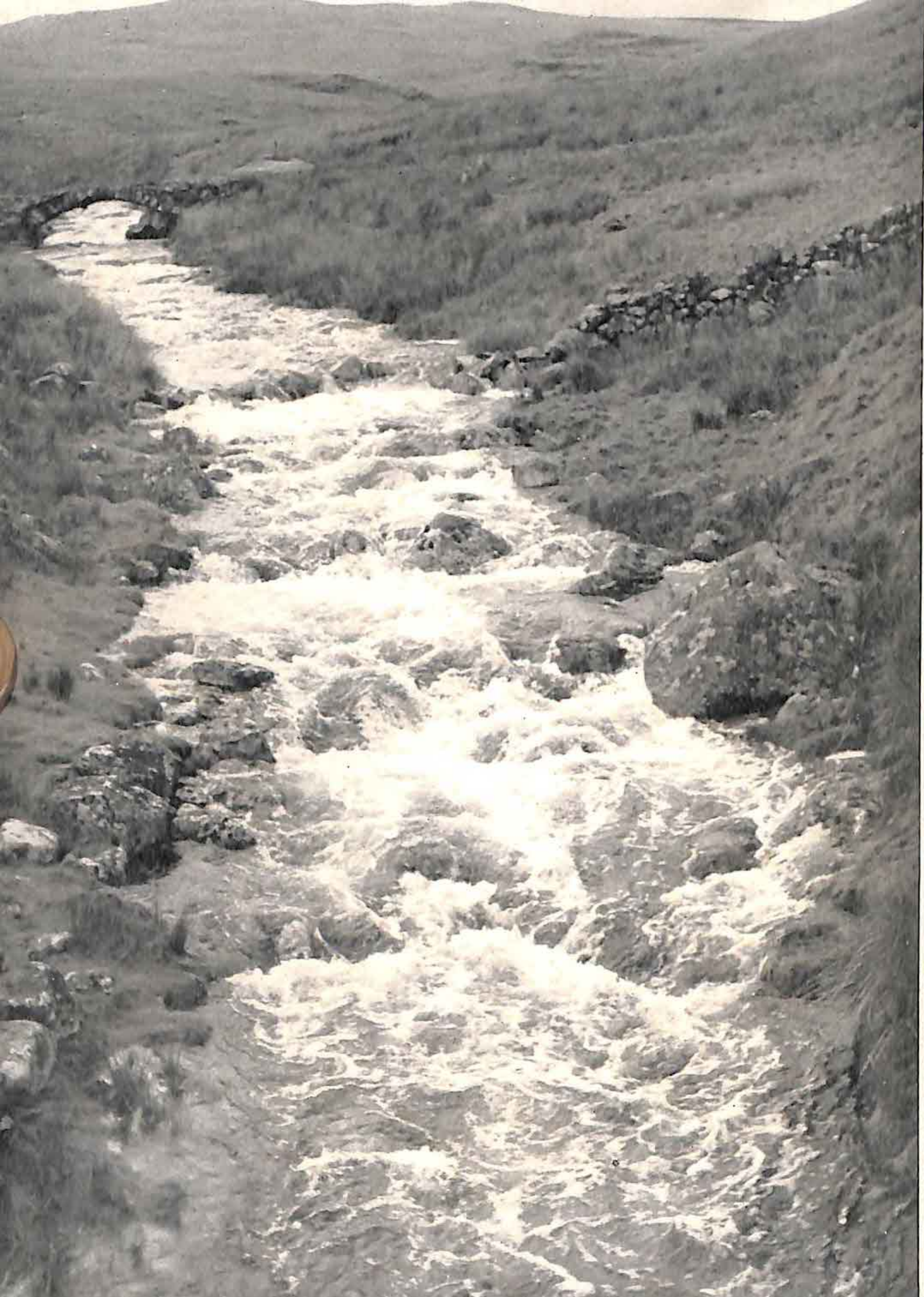

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Discovering Rivers

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Foreword

DISCOVERING RIVERS deals with its subject from many viewpoints. In it the author studies a river in relation to its countryside, to the rocks it flows over and the gradients it falls down on its way to the sea. She studies it in relation to its history – in geological time, when it wore away rocks and soil and carved out its valleys – and in human time, when men used it for transporting cargoes and built sluices and canals. She describes the uses to which man puts river water nowadays.

In Part I the reader is taken in imagination down the course of two rivers, starting in each case at the source itself and following the river down to the sea. He is shown how to measure the width of a river, the speed of its flow and the amount of soil it carries; and how to recognise the signs which reveal what a river is doing to its banks and its bed.

In Part II the author considers the work that rivers can be made to do and the ways in which their force can be used; for example, there are sections on water supply – with descriptions of reservoirs, dams and filter beds – and on water-power, in which we learn about some of the great hydro-electric schemes in various countries.

These are only a few of the many aspects discussed in DISCOVERING RIVERS. In addition there are photographs and line drawings which explain the text, and a list of suggestions for things to do that will take you out into the countryside, making notes in your log-book, observing, sketching and learning to understand something of the immense power of water, and to enjoy the pleasure that a river can bring.

ALYS L. GREGORY

Contents

PART ONE · Exploring Rivers

1 Man Discovers the Rivers

A valley with a stream in it is alive – alive with growing and living things, with the tinkle of little waterfalls and the glint of sunlight on the water. There are so many things to watch when you are on a riverbank: the way leaves and twigs sail on the currents, the water-weeds, and the plants and trees on the bank, the dark form of a trout darting beneath the stones, and, if you are lucky, the blue flash of a kingfisher. Most of our rivers begin like this, and not many of them grow very large, but in other regions vast rivers have become the great highways of the world.

Explorers in every part of the world have made use of rivers as they travelled into unknown lands, especially in North America, where the first European travellers used Indian canoes and penetrated far into the interior along the natural waterways they found. Here is part of a description of an expedition from Lake Michigan in 1670, led by Louis Joliet who hoped to find the Mississippi River:

'... The outfit of the travellers was very simple. They provided themselves with two birch canoes, and a supply of smoked meat and Indian corn; they embarked with five men ... Their course was eastward; and, plying their paddles, they coasted the northern shores of Lake Michigan; landed at evening to build their camp-fire at the edge of the forest, and drew up their canoes on the strand. They soon reached the Wild-rice Indians. The banks of the Mississippi, they said, were inhabited by ferocious tribes, who put every stranger to death, tomahawking all newcomers without cause or provocation. They added that there was a demon in a certain part of the river, whose roar could be heard

FIG. 1. They glided calmly down the tranquil stream

at a great distance, and who would engulf them in the abyss where he dwelt; that its waters were full of frightful monsters, who would devour them and their canoe; and finally, that the heat was so great that they would perish inevitably . . . The travellers soon reached the mission at the head of Green Bay; entered the Fox River; with difficulty and labour dragged their canoes up the long and tumultuous rapids; crossed Lake Winnebago; and followed the quiet windings of the river beyond . . . The river twisted among lakes and marshes choked with wild-rice; and but for their guides they could scarcely have followed the perplexed and narrow channel. It brought them at last to the portage; where, after carrying their canoes a mile and a half over the prairie and through the marsh, they launched them on the Wisconsin, bade farewell to the waters that flowed to the St Lawrence, and committed themselves to the current that was to bear them they knew not whither. They glided calmly down the tranquil stream, by islands choked with trees and matted and entangling grapevines; by forests, groves, and prairies; by

> thickets and marshes and broad bare sand-bars; under the shadowing trees, between whose tops looked down from afar the bold brow of some woody bluff. At night, the bivouac – the canoes inverted on the bank, the flickering fire, the meal of bison-flesh or venison, the evening pipes, and slumber beneath the stars: and when in the morning they embarked again, the mist hung on the river; then melted before the sun, till the glassy water and the languid woods basked breathless in the sultry glare. On the 17th June they had found what they sought, and steered forth their canoes on the eddies of the Mississippi. . . .'

Two centuries later great paddle-steamers, like the ones you associate with *Show Boat* and with Mark Twain's stories, carried hundreds of people and much cargo up and down the broad Mississippi.

All over the world rivers have been used for navigation by a variety of different craft. Sometimes it has been necessary for craft travelling upstream to be pulled against the current by teams of men walking along the banks. Travelling down river towards the sea is easier; the current helps to take vessels along, and in many forested regions of the world logs are tipped into a near-by river to float down to sawmills nearer the mouth. River navigation is still very important in many countries, though in Britain signs of it are not always obvious.

At all times river water has been used for washing and drinking, and in dry countries a continual supply of water may be very precious. In time it may even become revered. In Northern India the River Ganges is regarded as a holy river, and at Benares, which is a city built on the river bank, there are many temples, shrines and bathing places where people can worship.

One of the most valuable ways in which to make use of river water today is for the production of hydro-electric power. Engineers use the flow of a rushing stream of water to rotate turbine blades, which in turn revolve a dynamo and generate electricity.

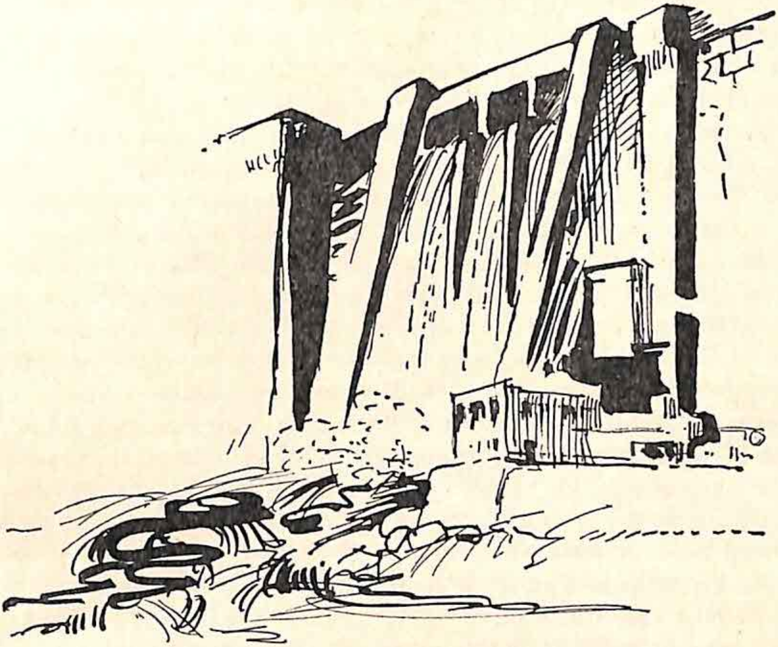

FIG. 2. Great steel and concrete dams have been built

In the last fifty years, in many parts of the world great steel and concrete dams have been built across the rivers; these dams store water for making electricity. One Australian project is particularly exciting. The water of the Snowy River is taken under the Australian Alps to be used to generate electricity on the other side of the mountains. This same water then flows on to the plains where it is used again to water millions of acres of dry land which, instead of producing only poor sheep-pasture, now grow fruit and vegetables.

This dual use of river water is common in many dry areas today. The electric power can be used not only to work the flow of water and light the homes of the farmers, but also to run factories which

can process the food grown on the irrigated land. But even when it is essential to use the river for power or for irrigation, many people regret the changes in the natural scenery which the building of dams entails.

Rivers always flow downhill and most rivers make their way into the sea, but in very dry areas a river may flow from melting snow on the mountains for some distance and then disappear into the sands of a desert, as do many of the rivers of Central Asia. Even the Sahara Desert has valleys, though usually they have no rivers flowing through them. They may be quite dry for many years, and then suddenly they are filled by a raging torrent after some distant storm. These valleys are called *wadis* and people travelling in them have been overtaken, and even drowned, by flood-water from a storm which broke miles away. Other areas – for example, round the Mediterranean or in monsoon lands – have rain at one season only and drought for the rest of the year. If you visit these places in the dry season, you will see waterless river beds, and may be surprised to see bridges where they seem unnecessary; yet if you returned months later, during the wet season, you would find rivers flowing beneath the bridges.

In mountainous areas the power of swiftly-moving water is increased when rivers are swollen by heavy rain or rapidly-melting snow. It can wash away great masses of rock and boulders, scoop out trees and hurl them towards the lower ground. Pictures taken at Lynmouth in North Devon on 15th August 1952 show the devastation caused by the small rivers, the East and West Lyn, which on that day were swollen by storm-water to a torrent.

The valleys of rivers vary greatly. Like the River Rhine, a river may flow steadily for hundreds of miles through a great fertile valley where many people farm and trade; or, like the Hwangho in China, it may be capable of flooding millions of acres, causing misery to the people living in its valley. In the United States, the Colorado River has cut a great gorge through which to flow, the famous Grand Canyon. Here the river flows 6,000 feet below the surface of the plateau, having cut its way through successive layers

(*above*) The River Teviot, Roxburghshire, Scotland
(*below*) A mountain spring in Yorkshire

of rock. The valley is very narrow at the bottom because this region is a dry area, so there is no water to run down the sides of the valley and, by wearing them away, to widen the valley floor.

Though most rivers eventually flow into the sea, the scenery at their point of entrance can differ widely. Along the North Atlantic coasts, in Europe and North America, the sea penetrates up many of the river mouths to form tidal estuaries like the great Gulf of St Lawrence, or the smaller Bristol Channel. However, many of the rivers of Africa and Southern Asia enter the sea through very flat tracts of land called *deltas*. These are continually being enlarged by silt dropped by the rivers as their waters reach the sea. This silt is usually very fertile, so much of the land in deltas is reclaimed for crops such as rice and jute.

Though rivers may vary greatly in size and speed of flow from country to country, there are many features which can be found on any river. Let us start by exploring one near by, the smallest stream you can find locally.

(*above*) The River Beaulieu, looking north-west from the Solent
(*below*) High Force, near Middleton-in-Teesdale

2 Discovering Your Nearest River

When you stand by your nearest river or stream and watch the water flowing by, do you think about where the water comes from and where it is going? Fig. 3 should help you to understand this.

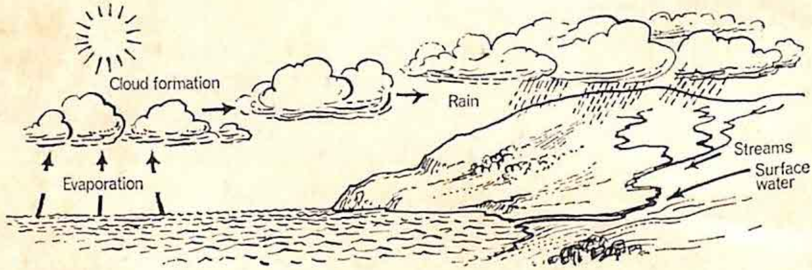

FIG. 3. The water cycle

Out over the oceans, the sun is drawing up moisture from the surface of the water and clouds are forming. The wind is blowing the clouds towards the land. When the clouds reach the land, they are cooled as they rise over the mountains and rain falls. This water flows into the streams and at last makes its way into the sea.

This movement is called the water cycle, because water is moving round through these various processes. In countries like Britain, where there is a damp climate, it is easy to follow this movement. We do not often have to wait long for rain and when it comes you can see water running down the road or off the rooftops. From the higher ground, where rainfall is heavier, water rushes downhill,

always seeking the lowest ground, running down gullies and ravines into valleys where rain has made its way for hundreds or even thousands of years.

THE SOURCE OF THE RIVER

The place where a river rises, or begins, is called its *source*. The River Beaulieu has its source in a patch of wet ground, as you can read in Chapter 3, and so does the River Tees, but rivers do not always begin in this way. The photograph facing page 14 shows a spring which is the source of a small stream. If you were walking down the hillside, you would notice a place where water bubbled out of the ground and found the easiest way to flow downhill to the nearest river. Sometimes the water comes out very slowly and is hard to see, but sometimes it bubbles and gurgles, making quite a song.

In some parts, the rock under the soil is so hard that it is impervious, which means that water cannot pass through it into the ground. In wet weather, water will remain on the surface in such places until it evaporates. It is on this kind of rock that streams begin, in a patch of muddy ground.

In south-eastern England, many hills are composed of pervious chalk or limestone, through which rain-water can seep. Ground water, as this seepage is called, moves slowly through the rocks. This process has been going on for long ages, so the rocks underground have become saturated and a vast amount of water is stored in them. There are, however, places where the pervious rock rests upon impervious layers, through which the water cannot pass. The water is held along the junction of the two kinds of rock and it is at this point on a hillside that a spring occurs (see Fig. 4). Where water comes from the ground it is usually pure, and often in the country people use this water in their homes, building a wall round the spring to keep animals away, and sometimes digging away the soil and stones to make a small well into which they can lower their buckets.

In a damp country like Britain, a stream quickly gains more water once it has started to flow. Water flows into the stream from the hillsides and fields sloping down to it, from rain falling on its surface and from water dripping from overhanging trees. The original stream is joined by other small trickles which have begun and collected more water in a similar way, and so it grows until a river is formed.

In different parts of Britain the word *stream* is very often replaced by another word: *runlet*, *runnel*, *brook*, *rill*, *beck* or *burn*. What is a stream called in your district? If you can visit the source of your own local river, go there and describe and sketch it. A change in vegetation – a group of trees, brighter green grass or clumps of rushes – may help you to recognise it from a distance.

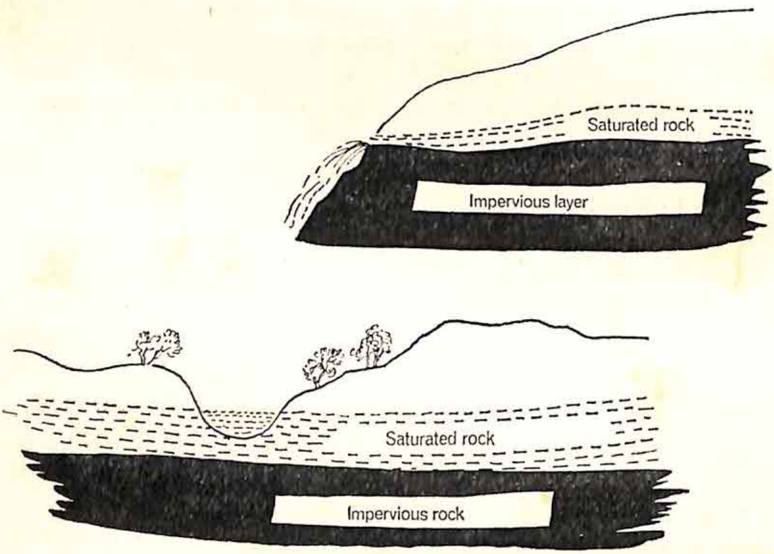

FIG. 4. Spring and lake where two kinds of rock meet

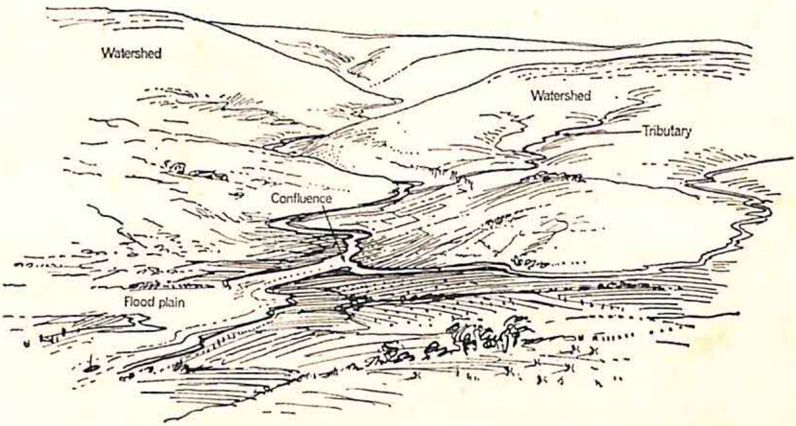

FIG. 5. The course of a river

THE COURSE OF THE RIVER

The course of a river is the way it takes through its valley to reach the sea. As you can see in Fig. 5, on its course a river will receive other streams which flow into it. We call these its *tributaries*. Fig. 5 shows the names given to a river and the land on either side of it. Think of your own river valley as you study this diagram.

THE SPEED OF A RIVER

Is the speed of your river always the same all along its course? Measure a distance along the bank, then throw in a stick. Count the number of seconds the stick takes to travel the measured length. Make a series of measurements at suitable places along its course. Set them out in a table under these headings: date, place, speed.

Do you know why the river runs faster in one place than in another? Is there any difference between its speed in summer and its speed in winter?

If you have no stop-watch, you must count evenly while a twig is travelling downstream and then count at the same rate at the next place where you want to measure the speed of the current. It will be easier to do this if there are two of you working together.

THE SIZE OF A RIVER

Measurements of the size (the width and the depth) of a river can be made at the same time that you measure the speed. If the river is a wide one, *do not wade* to the centre in case the water is too deep for you. Instead, go to the middle of a bridge and let down into the water a piece of string with a heavy weight tied to the end of it. Pull the string out and measure the part that has got wet – this will give you the depth of the river. However, it may not be possible for you to measure the depth if the bridge is very high, or if the water flows fast and drags the string along with it.

When you measure the width of a river, it will be easier to work with a friend. Throw a piece of string across to him, both of you make a mark or tie a knot where it touches the bank, then pull it back to one side and measure the distance. Be careful if the bank is muddy. Where the river is very wide, you may have to pace out its width across a bridge. If you cannot take any measurements, make a record in your notebook saying why measuring was impossible.

Measurements of the size of a river can be set out in a table under the headings: place, depth in centre, width, description of banks.

THE LOAD OF A RIVER

A river does not contain only water. After a wet day, you will notice that there is more water than usual in your stream and that instead of being clear it is muddy. Why is this?

Have you seen the river carrying pieces of twig and leaves? When it is moving fast it can also carry grains of sand and mud. Take a jarful of water from the river in dry weather and leave it to stand.

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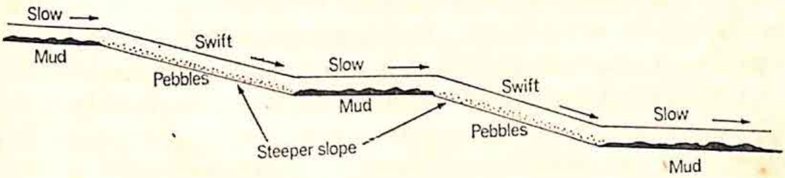


FIG. 6. Deposits on the bed of an English stream

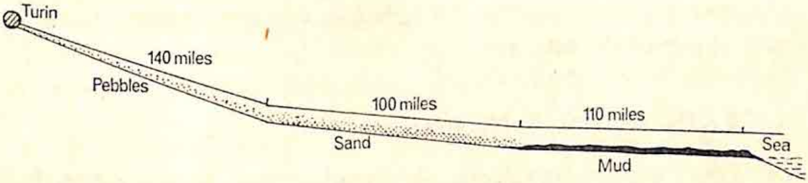


FIG. 7. Deposits on the bed of the River Po in Italy

Measure the depth of mud in the jar. After the next heavy rain, take another jarful of water from the river and measure the sediment in that. You will find that there is more mud at the bottom of the second jar. This shows that the river carries more mud when it is moving quickly.

When the river is moving along its bed, it carries not only fine mud but small pebbles as well. The faster the water flows, the larger are the pebbles it can carry. Pick up some of the pebbles from the stream bed and see how smooth and round they are. As the water moves them about they bump against one another and against bigger stones on the river bed, and so they get polished (see the upper photograph facing p. 14). Take some of them to add to your collection of specimens.

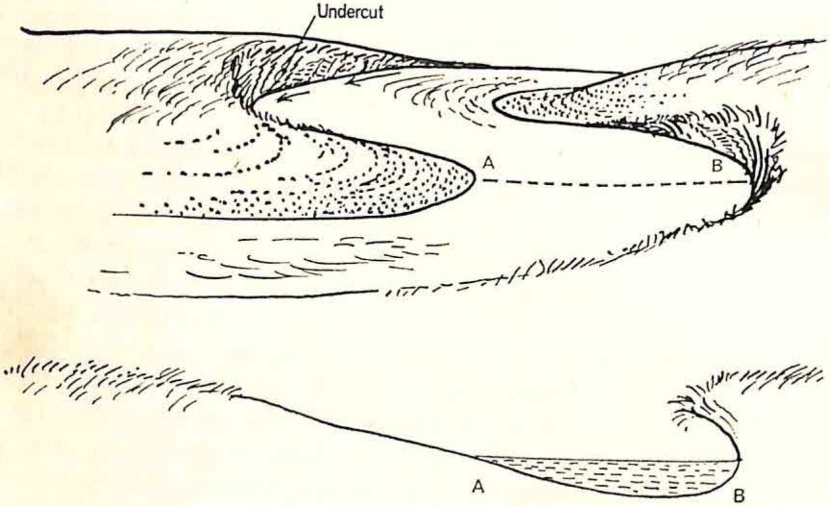
Some girls who were investigating a river discovered that their stream flowed more quickly when the land sloped down more rapidly. They found that where it flowed quickly its bed was pebbly, and where it flowed more slowly its bed was muddy. They drew a diagram of it like the one in Fig. 6.

You can see from the diagram what is happening. Where the

stream is flowing quickly, it carries the mud along and leaves the pebbles, but where it is moving slowly, it cannot carry the mud and drops it to the bottom. Is part of your stream like this too? Some scientists studied the bed of the River Po in northern Italy, and found that the pebbles, sand and mud were arranged as you see in Fig. 7. For 140 miles below Turin the water was moving fast enough to carry sand and mud, but dropped the pebbles; for the next 100 miles it could carry only the mud; and for the last 110 miles of the journey to the Adriatic Sea it was flowing so slowly that it dropped the mud too.

EXPLORING A MEANDER

If you have a curve on the course of your stream, go and watch the movement of the water there. It does not matter if it is only a small



Section across stream from A to B

FIG. 8. A meander

bend, for the movement will be the same as on a large one. Throw in sticks and see how they travel downstream.

At the outer bank, where the river flows more quickly, it cuts into the bank and into its bed. On that side, too, you will find a steep drop into the water. If there is a path along the bank, you may find that at this point it is being undermined and is falling into the river. On the inner bank of the bend, where the current flows more slowly, sand and stones are being dropped and a gravel beach is being built up (see Fig. 8). We call this curve a *meander*.

If you drop in sticks and watch them again, you will see that they move most rapidly on the outside of each bend, where a greater

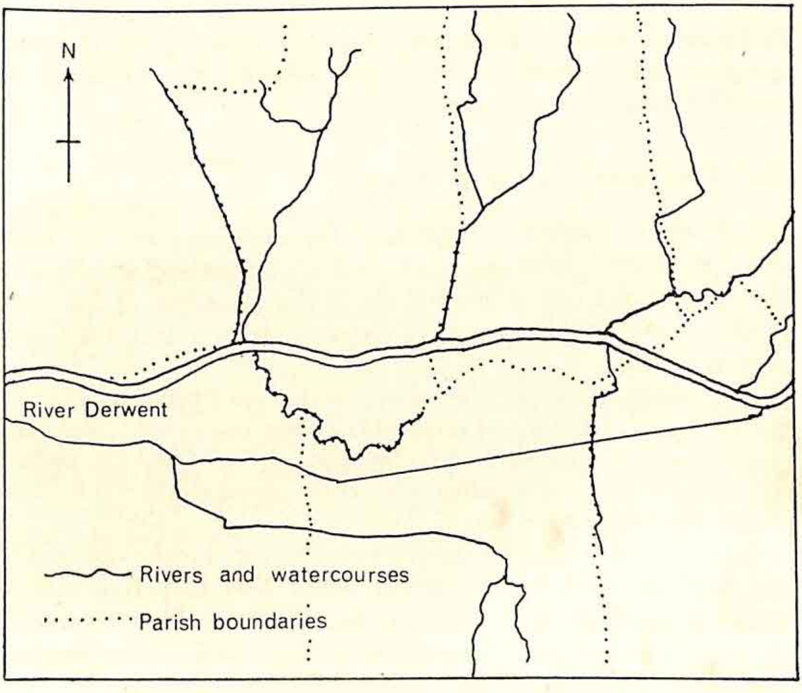


FIG. 9. Parish boundaries near the River Derwent

amount of undercutting is taking place. On the other side, the river is actually *making* firm ground and so the bend is moving downstream. We can tell that this has happened if we look at old maps and study the parish boundaries marked on them. You can see from the map in Fig. 9 that the boundaries are very near the River Derwent and have many curves in them. These remind you of the meanders of the river, but do not coincide with them exactly. Long ago, before men understood how the river changed its course, they used it as a permanent landmark to define the boundaries for their lands. But as the river shifted its course, it could be seen that some people were losing land to other parishes. So the old boundaries were kept and do not now coincide with the river at all. In this part of Yorkshire, which is known as the Vale of Pickering, engineers have made the course of the River Derwent straighter to prevent flooding. You can see the canalised or straightened part on the map.

THE BANKS OF A RIVER

The banks of rivers which are used for navigation are often cut away by the wash from boats. The farmers whose land stretched to the River Severn were worried about the condition of the river banks, so they had the speed of barges restricted until the banks were repaired.

The banks of rivers often have to be strengthened. Fig. 10 shows you various ways of doing this. Stone and concrete are used on bends where there is much undercutting. On straight stretches, where the strain on the banks is less, cheaper supports can be used which need not be so strong.

Examine the banks of your river carefully and make sketches of the methods used to strengthen them. You may find several different methods used within a short distance. How successful are they? Can you find places where the river bank is wearing away and repairs are needed? You could make a report on the state of the banks such as an engineer might make for his local council.

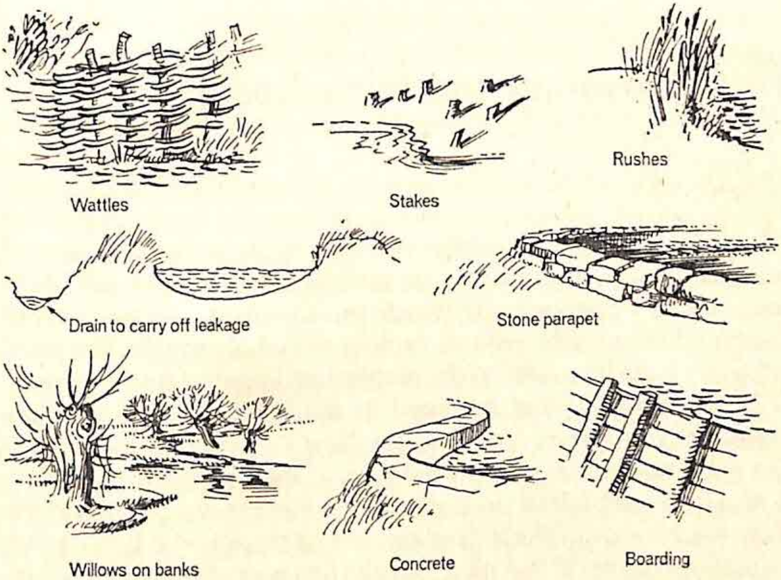


FIG. 10. Ways of strengthening river banks

The River Boards Act of 1948 divided the country into a number of catchment areas whose boundaries followed either the watershed of a large river and its tributaries or that of a number of smaller rivers. In addition to caring for the banks, the navigation, the fishing rights and the prevention of river pollution, the River Board measures the rainfall and river flow which will give information about the amount of water available in this crowded country. You may see one of these measuring stations on your river and be able to talk to the engineer when he visits it.

3 Discovering the River Beaulieu

Let us look at the whole course of a river, beginning with a small one. Some of you who live near the sea may be lucky enough to have a small river near by which you can explore from start to finish; others may be able to explore the whole course of a small tributary from its source to the place where it joins a larger river.

In the south of England, opposite the Isle of Wight, there is a stretch of Hampshire known as the New Forest. The higher parts are open heathlands and oak woods and dark plantations of coniferous trees are found on the lower ground. Several small rivers flow southwards to the Solent and one of these is the River Beaulieu. To pronounce 'Beaulieu', say the first part of the word 'beautiful' and add 'ly'. Beaulieu is a French name meaning 'beautiful place'. It was given to a site half-way along the river where Cistercian monks built a monastery in the 13th century. If you have not visited this district, find its position on a map. The River Beaulieu may not be marked as it is very small, but Fig. 11 shows a map of its course.

On the road from Southampton to Lyndhurst, after leaving the houses behind, you travel through the New Forest for the last three miles. If you stop a mile from Lyndhurst and walk off the road, you will find that it is very wet underfoot. Almost everywhere water will squelch out beneath your feet, although at first sight the ground may appear quite dry with tussocky grass or clumps of heather. In this marshy ground near the road several streams rise and form the upper part of the River Beaulieu. If you search in this area, you will find some stretches that are much wetter than others, sometimes with pools of water between the grass and heather. You will also notice that the land is not quite

flat and that the water is standing on the lowest parts. You will see that the land everywhere slopes a little to the south. Wade through the wettest parts in this southerly direction until you notice the water beginning to trickle and then to flow. You have discovered the source of a river.

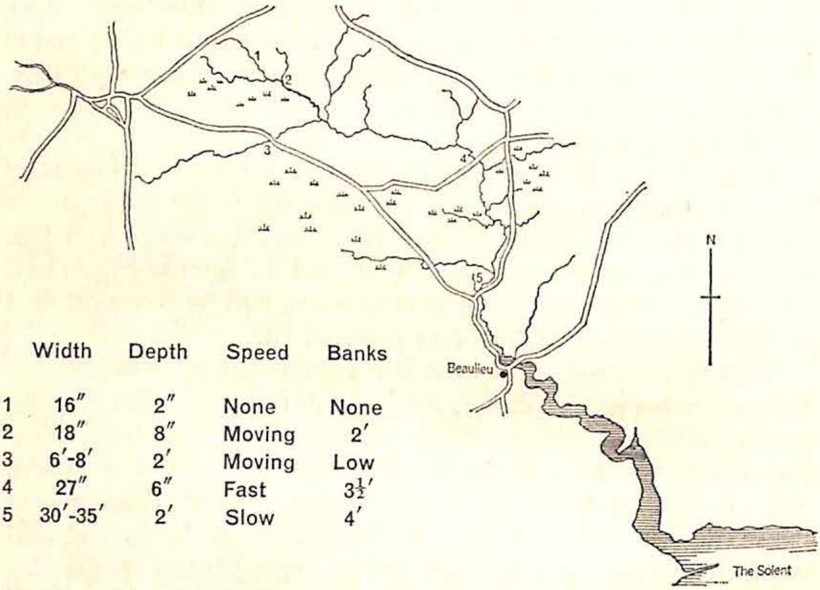
If you follow the trickle along, you will see that it is joined by other trickles, until some are bigger than others and finally one is big enough to be called a stream. The boggy area and the trickles of water flowing into one another we call the *source* of the river. Many (though not all) of our British rivers rise in this way; that is, they begin in a patch of very wet ground.

There are several small streams rising like this on either side of the main road to Lyndhurst, and they all flow together to form a moving stream in Ashurst Walk. As most of the land over which the tributaries of the River Beaulieu flow is in the New Forest, you can cycle and walk to nearly all parts of it. Thus a group of girls was able to collect many measurements of the streams and build up the record which is given in Fig. 11. Here are the descriptions they wrote and the sketches they made, at the five places where they stopped.

South of Mallard Wood a bridle path crosses the small stream by the bridge shown in Fig. 12. Here they stopped to make the following investigations (see 1 on the map in Fig. 11):

(i) examination of the bridge;
(ii) measurements of the stream at the bridge;
(iii) measurements of the stream above and below the bridge;
(iv) sketches of the bridge and the stream;
(v) descriptions of the scenery;
(vi) maps of the area.

Although the stream is very narrow, it flows in a small valley about 30 feet wide; there is a slight slope of three feet from the drier ground of the open heath to the boggy ground round about the stream. On the day the girls visited the stream it was about three feet wide and four inches deep, but after heavy rain it would



	Width	Depth	Speed	Banks
1	16″	2″	None	None
2	18″	8″	Moving	2′
3	6′-8′	2′	Moving	Low
4	27″	6″	Fast	3½′
5	30′-35′	2′	Slow	4′

FIG. 11. The course of the River Beaulieu

become wider as more water trickled down from the north. The wooden bridge is four planks wide, the width of the stream bed, as the stream has been shut in by stone walls and two causeways of broken stone have been built to carry the path over the boggy ground on either side (see Fig. 12). To the north was the flat marshy ground out of which came innumerable trickles of water to form the stream.

The girls followed the stream into Ashurst Walk, squelching through the muddy water for 300 yards, after which the stream changed. Instead of flowing through marshy patches, it now had banks and a gravelly bed and flowed much more swiftly; for the first time they could see that it had begun to flow downhill. It continued like this for forty yards and then was joined by another stream from the west in a confluence (see Fig. 13). The first stream had been at a higher level than the other one and for the last forty

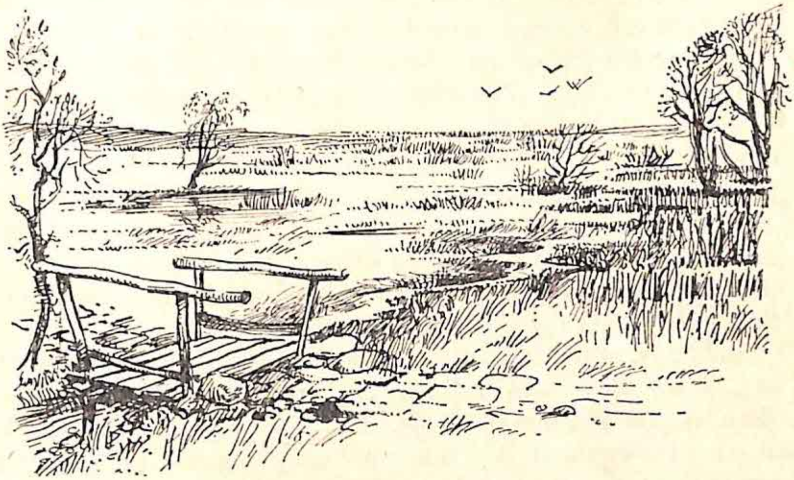


FIG. 12. The bridge crossing the River Beaulieu south of Mallard Wood

yards it had run downhill to reach the bed of the second stream (see 2 on the map in Fig. 11).

Where the children are shown playing in Fig. 13, you can see that the river has already begun to meander, with deeper pools and gravelly shallows on alternate sides. Notice how the banks differ. Can you say which is the deeper side?

Farther south the girls found that a branch of a tree had fallen across the bed; the stream tumbling over it made a small waterfall and for the first time in the search they heard the tinkling noise of falling water.

To the south-west, the road from Lyndhurst to Beaulieu crosses another tributary with the interesting name of Matley Bog. Perhaps you can explain the name Matley Passage (see 3 in Fig. 11) which is printed on the Ordnance Survey maps at the point where the road crosses the river.

If you visit the bridge (4) where the road crosses the river near Ipley Manor, you will see that the tributaries have brought down a great deal of water, for the river is much wider and deeper now.

Where the trees are scattered you will see that the river is flowing in a slight valley and that the land rises on either side.

At Leygreen Farm, a mile below Ipley Manor (5), the river flows alongside the road into Beaulieu village, but for most of this part of its course it is hidden from view by trees and hedges. This is the only part of the river that flows through farmland. The farmers have cut many ditches from their meadows into the river to carry away the water, so that the meadows can produce rich grass for dairy cattle. Thus, although not many tributaries are marked on the map in this stretch, the river is gaining water all the time from the ditches and so gradually becomes larger.

Suddenly, at the turn of the road, the river has disappeared and at high tide there is a small lake in its place, with Palace House, Beaulieu, on the opposite side. The tide plays a great part in altering the appearance of this lake because, as the tide ebbs, the lovely sheet of water vanishes and at low tide there is a great area of dark mud sloping down to a little river, which is the fresh water from the north still flowing on to the sea. This is the point where the fresh water of the river mixes with the salt water from the sea, but, as you can see from the map, there are still several miles of winding estuary before the open water of the Solent is reached. Here above the village is the tidal limit of the estuary. At the end of the lake, on the western side, lies Beaulieu, a single street of brick houses with red roofs, a large hotel and a handful of shops. Goods were once brought by sea to the quay, but today they come by lorry.

The lake above the village is not natural but man-made. It is really a large mill-pond. At one end of it the road crosses by a bridge and here you can see the mill. Before the mill was built, the tide flowed northwards at this point, as far as it could up the river, which became narrower and narrower. In the Middle Ages, men changed the appearance of the land at Beaulieu by building an earth dam across the valley with a gate or sluice in the centre. The mill was built beside the dam. The tide flowed through the sluice to fill the pond until high water, when the sluice was shut.

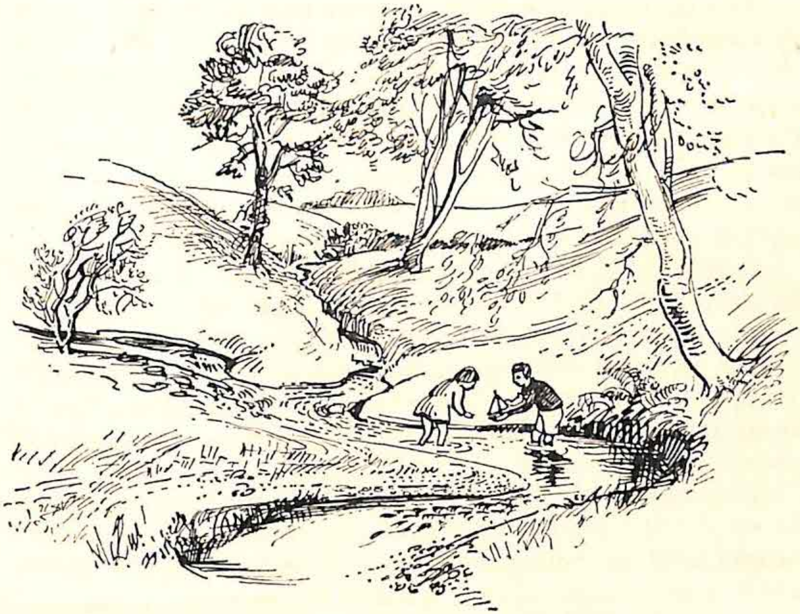


FIG. 13. A confluence on the River Beaulieu

As the tide ebbed, the level of the water below the mill went down until there was quite a difference between the level of the pond and the level of the water in the river below. At about half tide, water was taken from the pond through a mill race over the mill wheel to turn it and was then released into the river again. The mill could work while the flow of water lasted. In this lowland country, where there is not sufficient fall of water in the river to work the mill, men were glad to let the tide do it.

The mill was probably built by Cistercian monks who settled at Beaulieu Abbey at the beginning of the 13th century and may have been the first farmers in this district.

There are several of these tidal mills round this coast. If you live near the sea you may know of one near you.

From the village of Beaulieu, there is a path along the river bank which gives one of the loveliest walks in the country. The river is more than a quarter of a mile wide because the sea has covered the lower ground of the meanders. Fields and woods reach down to the water's edge at high tide. Often there are yachts on the river, for this is a favourite anchorage. At low tide, instead of water stretching from shore to shore, there is a waste of mud and stones crossed by small trickles of water at the bottom of the river.

Nearer the Solent is the other small village on the banks of the Beaulieu River, Buckler's Hard. A *hard* is the name given in this district to a slipway across a gravelly shore: a place where ships can be launched without getting stuck in the mud. Buckler's Hard was a naval shipyard in the days of wooden warships. Visitors today are surprised to know that the *Agamemnon*, a battleship of Nelson's day, was built here.

At the bottom of the street, near the river, there is a large house in which the master-builder lived. He planned the ships here, arranged for the cutting and hauling of timber from the near-by forest, and from his window watched the ships being built.

South of Buckler's Hard the river becomes wider and the ground on either side lower (see the photograph facing p. 15). Another mile and the sea lies ahead round the bend – not the open sea, but part of the Solent between the mainland and the Isle of Wight. Just as higher up the river, so here there is a difference between high and low tide. At low water a channel winds among the mud flats which are covered with spartina, a cord-grass which can withstand salt water. When the water is high the channel is deeper than the rest of the estuary. Poles have been placed in the mud to mark it.

The Beaulieu River rises on the lonely moors and flows as a small stream through the forest. Below Beaulieu, it is a broad tidal river known to yachtsmen, but nevertheless it enters the sea in a lonely place. Many British rivers are very different. In the next chapter you will see how to study the course of a larger river.

4 Exploring the River Tees

In the last chapter, we studied the course of a small river in the south of England, a little stream which flowed gently into the English Channel. Perhaps you are lucky enough to live near a stream like the River Beaulieu and will be able to walk from its source to the mouth in one day; but for many of you this will be impossible, because most of the rivers of Britain are too long. For example, if we wished to explore the River Tees in the north of England, a car or a bicycle would be a help, for it is seventy-five miles from its source to the sea.

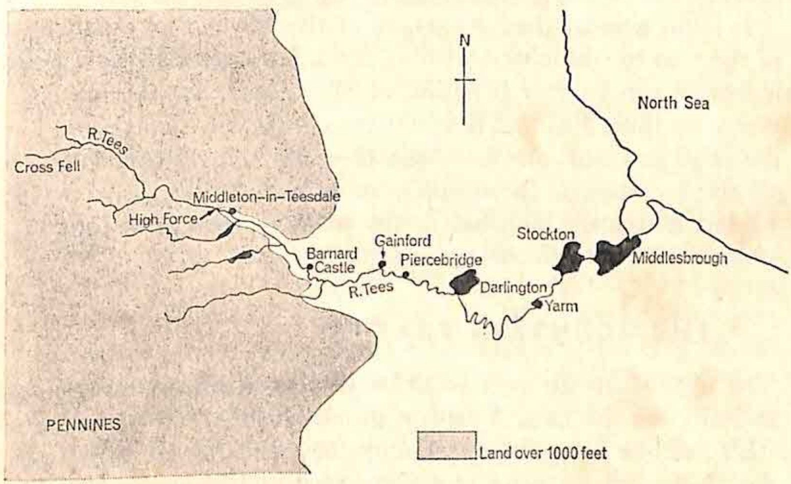


FIG. 14. The course of the River Tees

The map in Fig. 14 shows you the River Tees, which flows from Cross Fell in the Pennines eastwards to the North Sea. For the greater part of its course it forms the boundary between counties, first between Westmorland and Durham, and then between Durham and Yorkshire. The River Tees rises at Tees Head, a bleak waste of moorland on the eastern side of Cross Fell, at a height of about 2,600 feet above sea level. In every direction there are dark pools of water, separated by clumps of ling and tough grass.

There are no roads near Tees Head, and it is one of the loneliest places you could find in England. The only track near it comes round Cross Fell from the west. This begins in the valley of the River Eden at the village of Blencarn and passes over Grumply Hill, Wildboar Scar and Kirkland Fell to the summit of Cross Fell. It is not a good route for the exploration of the upper Tees valley, as there are four and a half miles of hard climbing to heights of over 2,000 feet, so you would be tired before you reached the source.

It is no wonder that the source of the River Tees is left most of the year to whinchats, curlews and a few sheep. If the weather is fine, it can be very beautiful at Tees Head, but the rainfall is heavy on these Pennine heights; the clouds can come down low, the wind can roar, and in winter the snow can drift, blotting out all the landmarks. In summer, snow-ploughs lie ready for the winter, fences are built beside the roads to prevent drifting, and stone shelters for the sheep are put in repair.

THE MOUNTAIN TRACT

The wet moorlands are covered with peat which acts as a sponge and absorbs the rain. A stream usually begins in a slight hollow which can be recognised by clumps of rushes. From such a place dark brown water seeps out of the peat and begins to run down when the slope becomes steep enough.

Once the streams have started to flow, they take a fairly direct

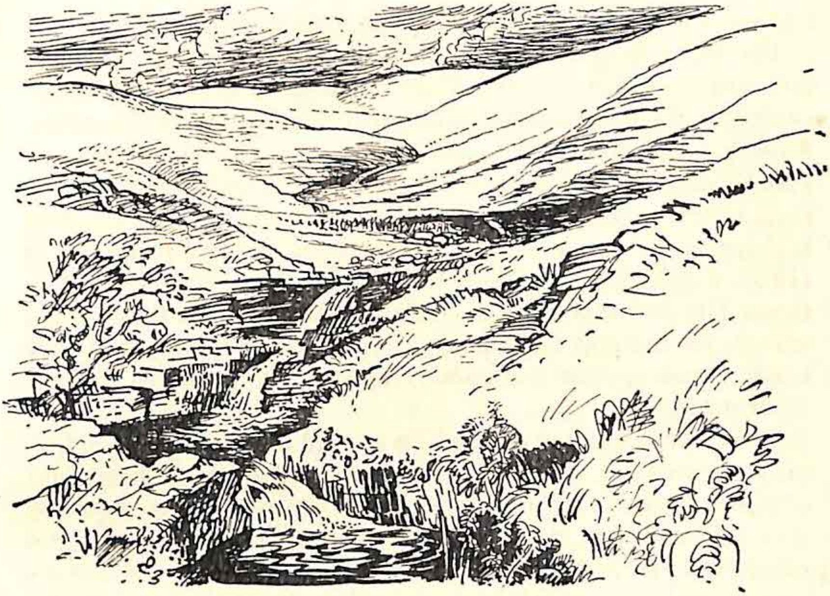


FIG. 15. A mountain stream

course, jumping over boulders in their way, tinkling on the stones, making small waterfalls or cascades, as you can see in Fig. 15. Here the brown water gathers a white froth of bubbles which makes it look like ginger beer, and when the sun shines on the falling water it gleams like yellow glass. There are many such streams flowing down from Cross Fell to join the River Tees, which gets larger as more water flows into it. The slope here is steep, so the river rushes downhill with considerable force. It falls 700 feet in the first two miles and 1,000 feet in the first eight miles. Flowing so quickly, it moves the stones in its bed about, so that they gradually become rounded from rubbing on each other. After heavy rain or rapidly melting snow, so much water tumbles down that pebbles are dragged along the bed and rub off pieces of rock from the

bottom. This makes the valley deepen until it becomes V-shaped.

The valley is also getting wider all the time from the action of rain and frost (see Fig. 16). Each raindrop as it plops upon the earth acts as a miniature bomb and sends up a shower of particles, some of which gradually move down to the river. In winter exposed rock is cracked by frost. Water seeps into the cracks in the rock, freezes, expands, and so widens the cracks; in time the rock is shattered. Near the top of Cross Fell you can find many pieces of rock with rough, sharp sides showing where the frost has broken them. The frost continues to crack them until the pieces are small enough for the rain and running water to carry away; then they begin to rub against one another and become rounded like the other pebbles.

The rainfall is heavy on the hills around the Tees basin and, as the rocks are hard, very little water soaks into the ground and most of it flows into the streams. Some of the streams rise very quickly after rain and may even flood their valleys, but the level of the water falls just as quickly in a dry spell. Many of the slopes are covered with peat, which holds the water, and so the upper course of the river affords sites suitable for building reservoirs. In Lunedale and Baldersdale the Tees Valley Water Board collects and stores water for the large towns near the mouth of the Tees. A new dam has been built at Selset, above the existing reservoir in the River Lune valley.

After crossing a flat, open stretch of lonely moorland, the river comes to the most exciting part of its course. Quite suddenly, it tumbles down a giant rock staircase, 200 feet high and less than half a mile long. Cauldron Snout, as this waterfall is called, is one of several in this district. They all occur where a layer of harder rock, a volcanic rock named dolerite, occurs above the limestone like a sheet (or *sill*, as geologists call it).

When I visited Cauldron Snout, I turned off the footpath called the Pennine Way, where it crosses the Tees by an ugly iron bridge. Here there was no sign of the waterfall. The River Tees flowed steadily on, but there was a thundering noise in the air.

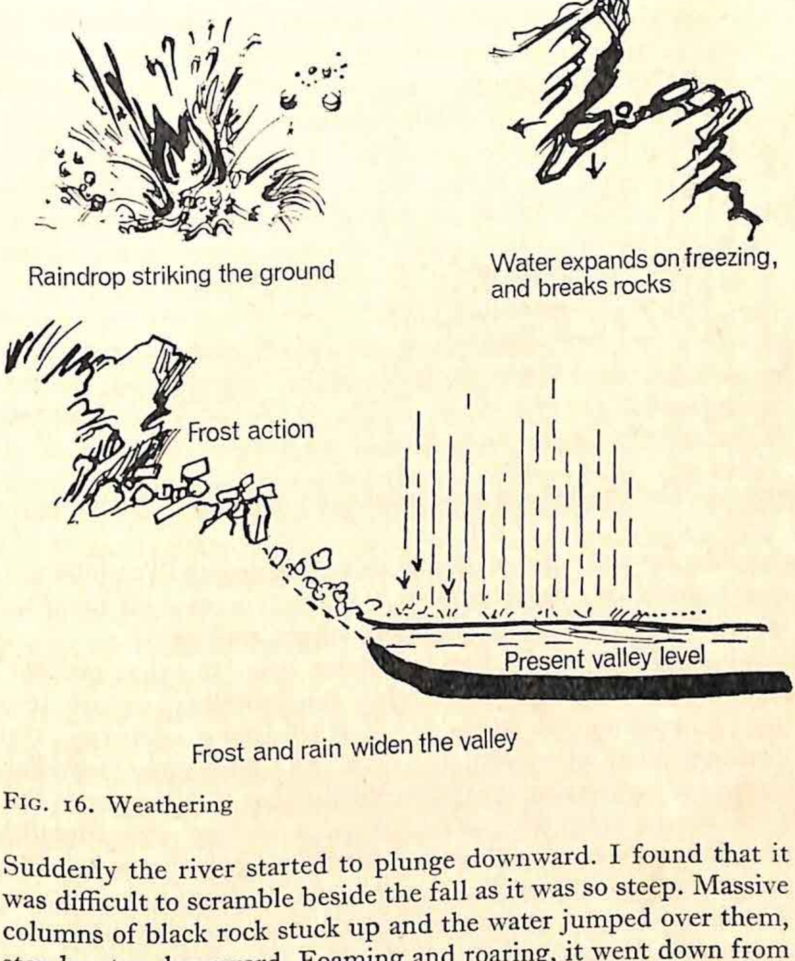


FIG. 16. Weathering

Suddenly the river started to plunge downward. I found that it was difficult to scramble beside the fall as it was so steep. Massive columns of black rock stuck up and the water jumped over them, step by step downward. Foaming and roaring, it went down from ledge to ledge making the noise I had heard when I was above by the bridge. The last leap, at least four times as steep as the others, ended in a great pool, around which was a jumbled mass of dolerite blocks which had fallen from above. The river is joined here by a tributary from the west called Maize Beck, and together

FIG. 17. The action of water on dolerite and limestone at High Force

they flow through a narrow valley called Holmwath. The hills rise steeply on either side for more than 300 feet; on one side the cliffs are called Falcon Clints, and on the other Cronkley Scar.

A little farther on the Tees falls down again, this time over the most famous waterfall of all, High Force, more than seventy feet high, (see photograph facing p. 15). It is easily reached from the road and today many people visit it. An 18th-century traveller (Nathaniel Spenser in 1773) described it thus: 'The water of the river, having collected itself together at the top of a frightful precipice, falls down with such a prodigious roar that it is heard at a great distance; for the perpendicular is twenty-three yards. The force of water dashing against the rock fills the mind with horror, but the scattered rays of the sun shining through the misty particles gives the whole the appearance of the most beautiful rainbow. The whole scene is so amazingly delightful that the spectator is lost in admiration at the infinite wisdom of the Creator of the Universe, and filled with the most elevated notions of His power and Majesty.'

I do not think that you would be filled with horror, but you must remember that whereas today we drive up in a bus or car and know that we are not far from towns and are sure of returning safely to them, the 18th-century traveller had set off into a rough, wild land when he came up the dale, and was not sure that he could find the way back.

Just as at Cauldron Snout, at High Force the River Tees tumbles over a hard sheet of dolerite. This is part of the Whin Sill which comes to the surface at several places in the north of England. Beside the road above the fall there are several quarries, as the hard whinstone makes excellent road metal when it is crushed. Dolerite is one of the hardest rocks and the river cannot wear it away, but the water does wear away the softer limestone below it. This leaves a lip of the harder rock over which the water tumbles. As more and more limestone is worn away, the valley below the waterfall gets deeper and the waterfall itself higher (Fig. 17). When you watch the water whirling around in the pool beneath the fall you will see the little waves hammering unceasingly on the rocks. These rocks are softer limestone and are dislodged and moved away so that the harder dolerite often overhangs.

You may find a tunnel behind a large waterfall where the pool beneath the waterfall has been enlarged by the wearing away of the soft rock. The hard rock at the top projects over the pool and forms a roof. Sometimes you can creep into the tunnel behind the white curtain of falling water. What a noisy place it is as the water splashes into the pool! Occasionally a piece of the overhang falls into the water.

As the river can wear down the edge of the fall for its own width only and not right across the whole valley, the river below the fall flows through a deep and narrow gorge. The gorge is very beautiful, as trees and ferns grow among fallen rocks and in cracks. People come long distances to see it. At the end of the gorge, the valley is much wider; in places as much as half a mile of flat land extends on either side of the river. In a short distance we reach Middleton-in-Teesdale, the first town in the valley. It is not very

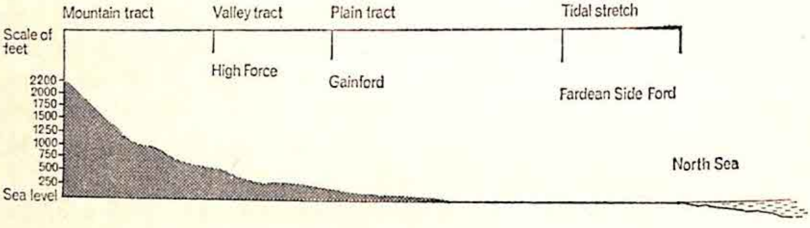


FIG. 18. The fall of the River Tees from its source to the sea

large and to many of you who live in cities it would seem like a village. The main street is very wide and there are stretches of grass and many fine trees growing between the roadway and the buildings.

Fig. 18 shows you how the River Tees falls from its source to the sea. It divides naturally into three sections:

1. The mountain tract, from the source to High Force, in which the river falls a great deal;
2. The valley tract, from below High Force to Gainford, in which the river falls less steeply;
3. The plain tract, from Gainford to the sea, in which the river falls very little.

You could say that the mountain stream leaps down the steep slope like a child jumping about, but as the river valley becomes less steep, the river is more even in its flow, more like an adult. Finally, the slow-flowing river of the plain section is like an old man who shuffles about very slowly and not very steadily, sometimes tottering from side to side. Perhaps Tennyson had something like this in mind when he wrote his famous poem 'The Brook'.

Fig. 19 has three maps which show you the River Tees in its three tracts, mountain, valley and plain. In each map the highest land is shaded, but notice that the shading does not represent the same height in each map.

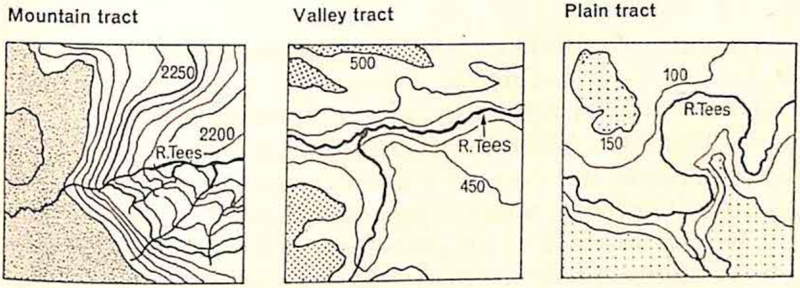


FIG. 19. The River Tees in its three tracts, mountain, valley and plain

THE VALLEY TRACT

From High Force to Gainford the Tees flows in the valley tract, where the valley is wider, lower and flatter than it was in the mountain tract. On the south side there are fine crags, such as Holwick Scar and Crossthwaite Scar, but the northern slopes are gentler. This part of the Tees valley is famed for its scenery. The sides of the valley are wild moorland and the lower ground, where the river meanders over the flatter floor, is cultivated.

The land is more level than in the mountains, so the river does not jump down waterfalls and over rocks but flows steadily along. In dry weather, when there is less water in the river, many banks of pebbles are uncovered. As you would expect, the pebbles are smooth where they have been rubbed against each other when the flood-waters came down. At that time, when they were tumbled against each other, they also rubbed against the bed of the river. For much of the year, however, the pebbles here lie without moving at the bottom of the river, so they do not wear away the bed very quickly and the water carries along only the finer material. The work of wearing down the sides of the valley continues more rapidly. Pieces of rock are broken by the frost and the rain washes them into the river as before. Though the valley is getting wider in this section, it is not very much deeper.

As it approaches Gainford, the Tees is burdened with rock waste. It therefore flows sedately in a wide shallow valley. The most important tributaries, the Rivers Lune and Balder, join the Tees below Middleton. These are called *right-back tributaries* because as the water of the main river flows on to the North Sea, it is joined by tributaries from the right-hand side.

Very few people live in the mountain section of the river, but here in the valley there are more villages and some towns. We can also find signs which tell us that men have lived in this valley in the past. Near Cotherstone where the river turns east there are the ruins of a castle, and two and a half miles farther on 12th-century Barnard Castle rises above the river, surrounded by trees. The town is built on the steep slope above the river and looks down on the old stone bridge (see the photograph facing p. 64). These old fortresses are a reminder that this was formerly a border area between the Scots and the English. Barnard Castle also guarded a crossing over the river. The river here is wider and more difficult to cross than it was in the mountain section, so bridging points were guarded carefully.

Lower down, the river flows by Egglestone Abbey where there is one of the few toll bridges left in the north of England. At Rokeby the River Greta, which has come from Stainmore, joins the Tees. In the 19th century, the artist Turner painted a famous picture of this confluence, which is called 'The Meeting of the Waters'. This district is famous too because Sir Walter Scott wrote a poem called 'Rokeby' about it. When he was visiting his friend who lived here, he described it as 'one of the most enviable places I have ever seen, as it unites the richness and luxuriance of English vegetation with the romantic variety of glen, torrent and copse which dignifies our Northern scenery'.

THE PLAIN TRACT

Below Gainford, the River Tees enters its plain tract. The slope to the sea is very gentle here. As it flows round the meanders, the scenery is always changing and is often very beautiful; in many places the banks are wooded right to the water's edge.

There is more water in the river now, so it is deeper and the stones on its bed are no longer visible. The water is usually cloudy and muddy because it is carrying a great many fine particles of mud. When it entered its plain tract, the river was carrying a load of rock waste from higher up its course, but in this section it will gradually drop this material in its bed. Very slowly, the bed level will rise as more mud or sand is dropped on it.

If a heavy rainstorm higher up the valley sends more water down suddenly, there will not be room for it in the silted-up bed. It will be forced over the river banks on to the land on either side and the river will be in flood. When it has spread over the flat ground, the water will become still and the mud which it was carrying will be dropped, so that when the floods go down, they will leave a layer of mud over everything. This is very unpleasant for the people whose homes have been flooded; but rivers have built up fertile plains by flooding in this way, for the river brings a layer of fresh soil every time it floods. Floods must have been more frequent in the past than we realise today. Along the river bank from Darlington to the sea you will notice many embankments which have been built to protect the land from flood.

The highest point on the Tees reached by salt water from the sea, the tidal limit, is Fardean Side Ford. On the seaward side of Fardean Side Ford the tide rises and falls twice a day, as happened below Beaulieu (see Chapter 3). Where the fresh and salt water meet, the slight current of the river is checked and mud which it is still carrying is dropped. At low tide the mud banks are exposed.

For people travelling from north to south in this area, the Tees has always been difficult to cross. A town has grown up wherever

there is a bridge and it is interesting to see how these towns have changed in importance through the ages. The Romans built their bridge at Piercebridge, where their great road northwards to Hadrian's Wall crossed the river. Today the Great North Road (A.1) turns off the line of the Roman road to go north-eastward to Darlington. Lower down the river, Yarm became an important town because it was the last place where a bridge could be built across the Tees. As ships could sail to this point, Yarm became a port where goods carried by sea could be exchanged for goods brought by road. In the houses on either side of the cobbled street leading to the bridge were stored wool, hides, corn, salt and wine. The town was built in a great meander, so the river almost surrounds it and in the Middle Ages served to protect it. It is a pleasant, red-brick town, with old landing-quays beside the river, but now only pleasure boats tie up at them, for there is no more than four feet of water at high tide and sometimes as little as six inches at low tide. Nowadays, ships are too large to come up to Yarm, but there is still a bridge across the river and traffic hurries through the town on its way to Stockton.

The river meanders northwards from Yarm towards Thornaby, but then the meanders cease. At the beginning of the 19th century the river meandered all the way to the North Sea in a series of great S-bends, which gradually became wider and more sandy. A writer described it as 'silent and solitary, broken by the presence of a few grey-headed seals and a few shrimping women'. How different the Tees is today! There are great factories and towns on its banks, and the river has been controlled and deepened. Stockton was a small market town when Yarm was a port, but today Stockton is the chief town of this area.

Below the Stockton-Thornaby bridge (see Fig. 20), the course of the River Tees has been straightened in an effort to prevent floods. The old bend of the river can be seen round the racecourse at Thornaby and near Billingham Beck, but now the river is bounded between walls and flows along to the sea by a straighter course.

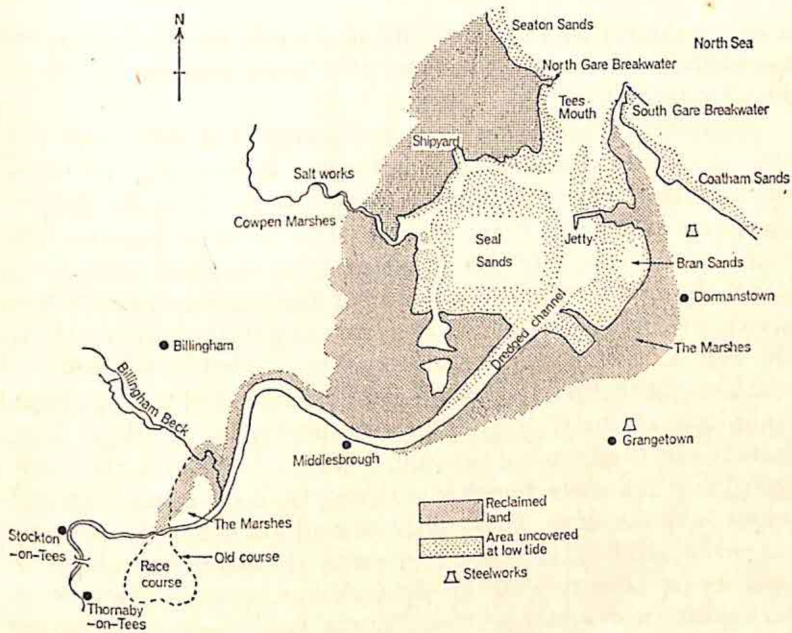


FIG. 20. The course of the River Tees below the Stockton-Thornaby bridge

Fig. 21 shows the depths to which the river channel has been dredged from Stockton to the sea. This is the navigable stretch of the River Tees.

Beyond Stockton are Middlesbrough and Billingham, two more industrial towns. Middlesbrough was once a lonely spot on the marshes of the estuary; even in 1800 there were only twenty-four people living in four farms there. By 1820, there were about forty people, but then change came quickly because the first public railway line was opened between Darlington and Stockton in 1825. It was continued to Middlesbrough in 1827 and a writer mentions that coal-staithes were built at the end of the railway line, on the lonely estuary, where the coal was tipped from the trucks into the small coasting vessels. (This was before the river was dredged as

far as Stockton.) By 1840, iron and steel works had been built on the southern side of the river and were using iron ore mined in the Cleveland Hills to the south.

Industrial Tees-side has been developing ever since, and the river has been controlled more and more. Before 1854 the navigation of the River Tees was controlled by the Tees Navigation Company which had been working since 1810 to improve the river; but the company had no powers over the eight miles from Middlesbrough to the sea, and it was said that sometimes this stretch was too shallow to get even a rowing boat along. In 1854, the Tees Conservancy Commissioners reclaimed 4,000 acres of marshland by the river. They ordered the building of walls through the middle of the river to form a deep channel for ships. The channel was dredged and the mud from the bed of the river was tipped over the walls, together with slag from the iron works and ballast from the ships. This reclaimed land was useless for farming but made excellent sites for ironworks, shipyards and chemical factories (see Fig. 21). Middlesbrough quickly grew into one of the greatest iron and steel towns in the world, and also became a port. It sends away the goods made in the near-by factories and foundries, and imports the things its population needs. The picture of the Tees near Middlesbrough is very different from that of the river in its upper course – the river is broad and sluggish, its waters are polluted with industrial waste and on its banks great factories have been built.

Near the estuary, it becomes more and more difficult to build bridges. The river becomes wider, the banks lower and less firm, and as the river is used by larger boats, the arches of the bridge must be high and wide enough for the vessels to pass underneath. Between Middlesbrough and Port Clarence on the north bank the problem has been solved by building a transporter bridge; this is the last bridge across the River Tees before it turns north and joins the North Sea.

The River Tees enters the sea through an almost enclosed bay (see Fig. 20). At low tide there is a vast stretch of sand and mud

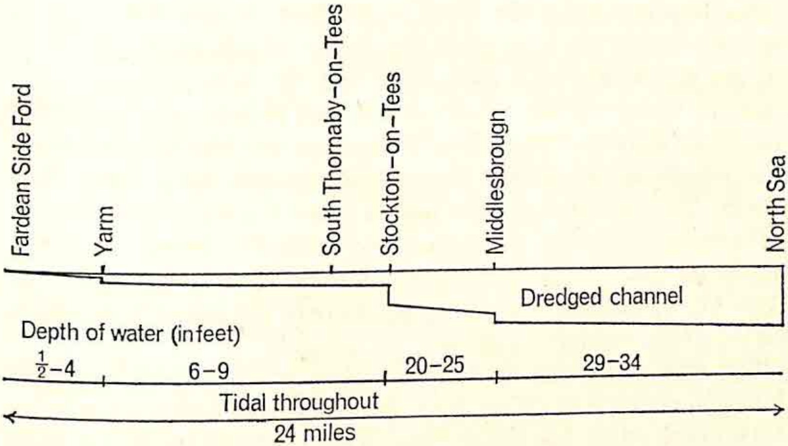


FIG. 21. Channel of the River Tees

across which there are a few permanent channels of water. The estuary of the River Tees is much wider and longer than that of the Beaulieu, and in place of beautiful woods sweeping down to the water's edge there are factories and desolate wastes (see the photograph facing p. 64). On one side is Billingham where there are chemical works, and on the other the great iron and steel works of Dormanstown and Grangetown. Breakwaters and sea walls, built of slag from the iron works, prevent the water from spreading from Seal and Bran Sands inland over the marshes to the west and east. These sand-hills and marshes are still being reclaimed and will provide future sites for industrial works. Since 1958 deep-water berths have been built in this area in addition to two new oil berths. This will mean that in addition to the large tankers the new berths will accommodate larger cargo liners.

At the northern end, the estuary is much narrowed by breakwaters. The South Gare lighthouse marks the point where the River Tees enters Tees Bay, a slight curve on the North Sea coast between Hartlepool and Redcar.

Our journey down the Tees is finished. If you look back to Fig. 14 you can see once again the course of this great river. You can see the bleak, high moorlands and the waterfalls; then the beautiful valley with its woods, castles and abbeys; and finally the great plain south and east of Darlington across which the river flows so slowly to the North Sea. You can see the tributaries which flow into the Tees and imagine the higher ground around them. This is the watershed (see Fig. 5). All the land within the dotted line on the map is drained by the streams which make their way to the River Tees. We call this drainage area the *basin* of the River Tees and it has an area of 708 square miles.

The watershed also marks the higher ground which separates the basin of the River Tees from the other river basins – the River Wear to the north, the River Eden to the west and the River Swale to the south.

You will be able to make a study of your own river now. If the source, or the mouth, or maybe even both, of your river are too far away for you to visit without an expensive journey, you can find out something about them by looking at a map.

At school you may have the local sheets of the $2\frac{1}{2}$-in. or 1-in. maps prepared by the Ordnance Survey, or if you want to possess your own copies you can buy them from a bookseller. (These maps will also be very useful to you when you go for walks or cycle rides.)

If your river is a long one, you may need the $\frac{1}{4}$-in. map to see the whole of it on one sheet. This map shows a larger area of land on the same size of paper. If your river is very long, you may need a map on an even smaller scale, like the one you will find in your atlas.

How to find out more about Rivers

In Part I you read of different ways of exploring rivers, and perhaps by now you have planned your own inquiry and are ready to set out on your expedition. As you stop on bridges to investigate or tramp across fields, you will discover many things about rivers that you will want to talk about. But a real explorer always keeps a log-book to be sure that his discoveries are not forgotten. Remember that a good log-book has maps, photographs, sketches and diagrams as well as written descriptions and explanations. Perhaps, if your river is a long one, you will decide that you will need a team of explorers and more than one log-book.

In Part II, you will find answers to some of the problems you meet on your search. The titles of the different sections will help you find the information you are looking for.

5 Water Supply

Water is something everyone needs. People used to take their water from springs, wells or rivers from earliest times until the 19th century, when scientists proved that river water was not pure. There are many ways in which river water can be contaminated (or made impure), but contamination is usually caused by dirty things or dirty water being thrown into the river higher up its course. Today, every water undertaking in this country purifies and tests the water carefully before allowing it to flow along the pipes to the houses.

Here are the chief ways in Britain of obtaining drinking water:

1. SPRINGS for farms and small settlements, and for a few towns such as Bath and Bedford.
2. WELLS which tap underground water. The greater number of towns in south-eastern England get their water in this way, e.g. Bournemouth, Brighton, Cambridge, Croydon, Southampton.
3. NATURAL LAKES, e.g. Manchester from Thirlmere in the Lake District, Glasgow from Loch Katrine.
4. RIVERS, e.g. London from the River Thames and its tributary, the River Lea, Aberdeen from the Scottish River Dee, Cheltenham from the River Severn, and Chester from the English River Dee.
5. ARTIFICIAL LAKES, called RESERVOIRS, which are usually filled by rivers. This is the way most of the towns in the north of England get their water – e.g. Birmingham, Bradford, Burnley, Leeds, Liverpool, Sheffield and Wakefield.

How is the water for your town obtained? Do you know where your waterworks are situated?

SPRING AND WELL WATER

Although we think of spring and well water as uncontaminated, yet towns which obtain their water from these sources purify it. Before 1939, Southampton obtained most of its water from wells in the chalk at Otterbourne, south of Winchester. Before it entered the pipes for the town, it was tested and filtered just as river water is. However, all the great ships which came to the port needed fresh water, so another supply had to be found. The nearest source was the River Itchen which flowed close by the wells, so the river water was pumped to the existing waterworks and passed through the same purifying processes.

NATURAL LAKES

Unfortunately, not many of our cities are near lakes, the best source for a water supply. Two of Britain's largest cities, Manchester and Glasgow, have thought it worth while to lay many miles of pipes to gain this advantage, though Thirlmere and Hawes Water are 106 miles from Manchester, and Loch Katrine is thirty-five miles from Glasgow. The cost of laying the pipes and keeping them in repair is offset by the fact that lake water is so pure that it needs very little treatment. As a result of this, water in Glasgow, for example, is cheaper than in any other great city in the world.

Lake water is also purer than purified water, and pleasanter to use. At first it was not understood why this should be so. It was known that in a still lake sediment such as grains of sand or mud sink to the bottom, but why should the water in Glasgow be so free from bacteria? It was discovered that if water is stored, then many of the bacteria die. When this was known, engineers realised that large storage reservoirs were not only useful to hold a reserve stock of water but also to help to improve the taste and appearance of the water. Thus reservoirs are a feature common to nearly all waterworks.

RIVERS

The water in many British rivers is not pure enough to be used for domestic purposes, yet our greatest city, London, takes most of its water from the River Thames.

In London, water is supplied by the Metropolitan Water Board, the largest water undertaking in the world, which pipes about 350 million gallons of water a day to over six million people who work and live in and near London. About sixty per cent of this water comes from the River Thames, but before it enters the pipes it is stored in large reservoirs for about two months, passing from one end to the other. Here the fine particles settle and many bacteria die. When it has left the reservoirs and before it enters the pipes, the water passes slowly, at the rate of about four inches an hour, through filters. It is made to flow through a container like the one shown in Fig. 22.

When the container is full, the inlet pipe is closed and the outlet pipe opened. The water flows through the layers of sand, the solid impurities which may be afloat in it are caught up by the rough particles of sand and the water flows on down. The purification process is completed by adding a little chlorine and finally the water is tested before it passes into the pipes for use. Water is so carefully tested as it leaves the waterworks that it is almost impossible for any contaminated water to reach the pipes.

The latest filter house, built at Kempton Park near London, has been fitted with more rapid filters in which a chemical is used to force the impurities to remain on the surface.

Nine large reservoirs together hold 20,000 million gallons of water for London. This is many days' supply, so it is rare for London to be short of water even in the driest summer. The reservoirs are always deep to prevent the growth of algae (i.e. waterweeds), which would give an unpleasant taste and smell to the water.

As the River Thames is a large river with a number of tributaries flowing into it, London is fortunate in being able to get a constant

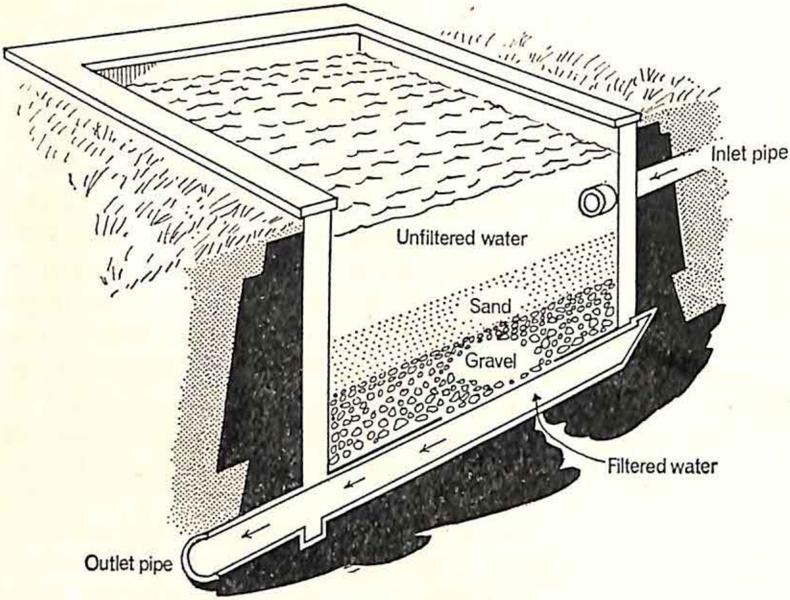


FIG. 22. Filtering water after it has left the reservoir

amount of water, but some cities in Britain use more water than the river on which they stand can bring them. A city cannot take all the water from a river, but must also let some flow on towards the sea for the use of other places further downstream.

RESERVOIRS

Many cities, especially in the north of England, collect and store water in artificial lakes or reservoirs which engineers build in hilly districts. A reservoir can most easily be built in the mountain section of a river where a wall or dam can be built across a river valley, making an artificial lake behind it. This can only be done where the underlying rock holds the water; otherwise it would merely sink into the ground and be lost.

STOCKPORT'S GOYT VALLEY WATERWORKS AND RESERVOIR

The River Goyt rises in the hilly country south of Stockport. After flowing northwards it joins the River Mersey near the centre of the town. Sometimes there is plenty of water in the river, sometimes very little, but engineers saw that a dam built across the upper valley would contain the flood-water, so that there would be enough throughout the year for the town's needs. About 1930 Stockport Corporation bought the land in the Goyt valley where many small tributaries drain into the river from the surrounding hills, and water engineers built a dam across the valley to form an artificial lake (see the map in Fig. 23).

BUILDING THE DAM

The diagram in Fig. 24 gives a section through the dam and shows the clay core or centre with earth piled against it on either side. On the reservoir side, where the water presses against it, the dam is faced with stone from Darley Dale not far away, but the other side is grassed over. Across the top runs a road enclosed by stone walls. Behind this dam, 5,000 acres of hill country on either side of the valley drain into the reservoir or into the River Goyt by many small streams and ditches.

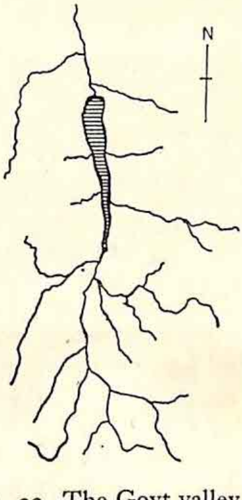


FIG. 23. The Goyt valley

Fig. 25 shows the dam, behind which is the reservoir. If there is too much water in it, the surplus can flow down the stone staircase on the left, but normally the water is taken from the reservoir by pipes in the tunnel on the right.

On the top of the dam, beside the roadway, is a small valve tower in which are the instruments for measuring the level of the water in the reservoir. Under it a shaft containing iron ladders for inspection purposes has been cut through the dam. The shaft is eight feet wide, and two large pipes thirty inches in diameter come out of the wall on the left and then curve down to join a large vertical pipe which continues to the bottom of the shaft, where it is joined by a third pipe. These three pipes at forty, eighty and ninety-five feet down the shaft are the outlet pipes from the reservoir, and are indicated by solid black lines in Fig. 26.

Usually the top pipe is open and the water is taken by it from the reservoir, but in dry weather the water-level in the reservoir may be so low that it is below the top pipe's mouth. Then the second pipe is used, and if the reservoir is very low the bottom pipe is used.

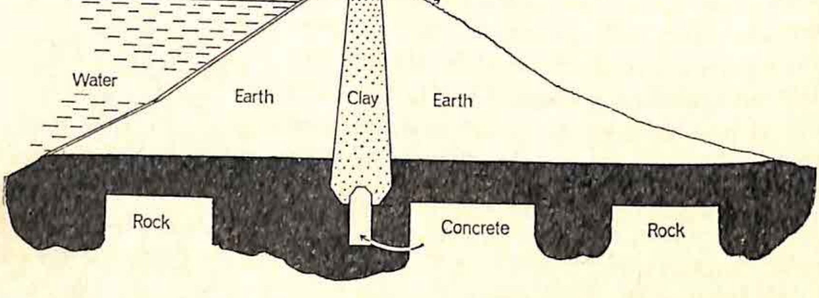


FIG. 24. A section through the Goyt valley dam

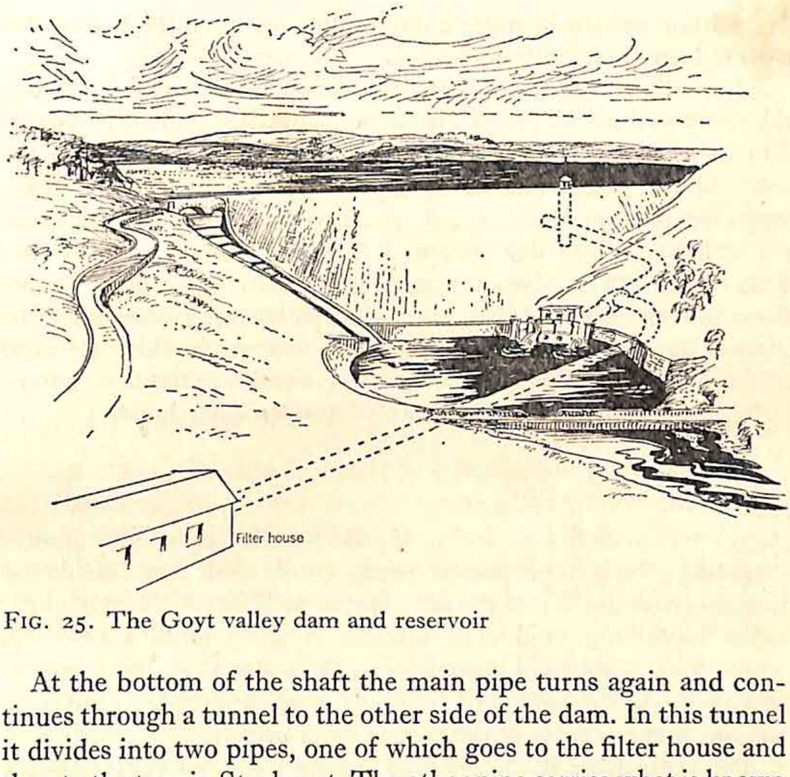


FIG. 25. The Goyt valley dam and reservoir

At the bottom of the shaft the main pipe turns again and continues through a tunnel to the other side of the dam. In this tunnel it divides into two pipes, one of which goes to the filter house and then to the taps in Stockport. The other pipe carries what is known as *compensation water*, and lets it flow out at the foot of the dam as the River Goyt again. The valves in the tower control the amount of water which flows through both these pipes.

COMPENSATION WATER

Stockport Corporation cannot take all the water from the River Goyt for use in the town, because lower down the valley there are many mills which have always taken water from the river for their own use. The second pipe in the tunnel allows two and a

half million gallons of water a day to flow on down the bed of the river to keep these mills going.

After falling from the reservoir and flowing through the pipes, the water as it comes out of the tunnel is flowing at great pressure. This is necessary to enable the waterworks to force the water up some of the steep hills in Stockport. Before the compensation water can be allowed into the river, it is passed into a series of great concrete basins to check its speed. The mill-owners and the officials of the River Mersey Catchment Board – the River Goyt flows into the River Mersey – are allowed by Act of Parliament to inspect the records about the compensation water which are kept at the dam, to see that the waterworks are carrying out their agreement and not taking too much water into the filter house.

FILTER HOUSE

As there is little flat ground in the Goyt valley on which to build filter beds, the water is passed through rapid sand filters inside the building near the foot of the dam. Rapid sand filters are large metal tanks containing sand and sulphate of aluminium, a chemical which makes any solid impurities in the water from the reservoir stay on top of the sand. The water is forced through the sand from the top to the bottom of the tank at great pressure.

The water from the peaty soils around the Goyt valley is often brownish in colour and is very soft, so in the filters the brownish colour is taken away and the water is hardened a little by means of other chemicals. Of course, the chemists are making tests all the time to see that the water flowing into the town pipes is pure.

Not all reservoirs have earthwork dams, as at Stockport. If a high barrier is needed, then stone or concrete is used to make a masonry dam. Many of these reservoirs are built in beautiful mountainous areas and they look like natural lakes if you turn your back on the dam. At Lake Vyrnwy, the reservoir in Wales from which Liverpool gets its water, the overflow tumbles like a waterfall over the dam itself when the reservoir is full.

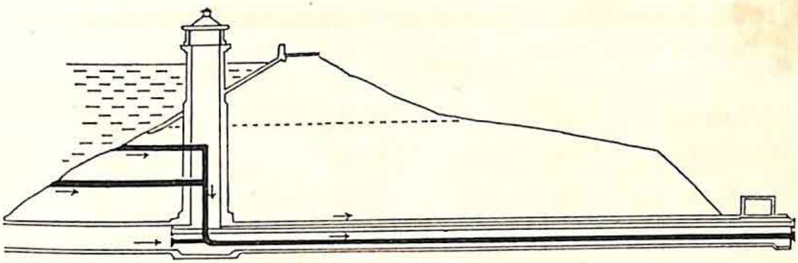


Fig. 26. A section through the valve tower of the Goyt valley dam

FISH LADDERS

When a reservoir is built on a river up which trout and salmon pass to their spawning beds, there must be a fish-pass or ladder up the side of the embankment into the reservoirs. The ladder consists of a number of pools one above the other. These are all connected by a continuous flow of water through which the fish jump, travelling from pool to pool as they press on to reach the gravelly upper parts of the river in which they lay their eggs. They can tackle getting up the fish ladder because it appears to them to be similar to a series of rapids which they are accustomed to meet on the upper courses of rivers which rise in high ground.

AQUEDUCTS

Where the lakes or reservoirs are far from the towns, the water is carried by aqueducts, either in tunnels, or by pipelines, or by first one and then the other. Loch Katrine's water passes through a tunnel eight feet by eight feet to Glasgow, and the water from the Elan reservoir in Wales goes to Birmingham in a tunnel five feet eight inches by six feet three inches. Often the building of these aqueducts presents problems to engineers, because of the many changes of level in hilly country.

Table of some of the largest British reservoirs and their aqueducts

TOWN	RESERVOIR		LENGTH OF AQUEDUCT
Birkenhead	*Alwen*	*Wales*	*47 miles*
Birmingham	*Elan Valley*	*Wales*	*73 miles*
Bradford	*Gouthwaite*	*Nidderdale*	*28 miles*
Cardiff	*Taff Fawr*	*Wales*	*30 miles*
Dundee	*Moni Rie*	*Grampians*	*25 miles*
Edinburgh	*Talls*	*Southern Uplands*	*34 miles*
Liverpool	*Vyrnwy*	*Wales*	*68 miles*
Newcastle	*Catcleugh*	*Cheviots*	*38 miles*

The quantities of water used in a modern city are very large, so that Manchester, for instance, takes water from the Pennines as well as from the Lake District. Instead of one large reservoir there are seven, stretching out in a line from Woodhead down Longdendale.

On the other hand, one river may serve many towns. For example, the water of the River Tees supplies several towns near its mouth. Darlington has its own waterworks, but for the rest of the people in the valley the water is controlled by the Tees Valley and Cleveland Water Board. The water is stored in reservoirs in the valleys of two tributaries as follows:

RIVER	RESERVOIRS	AMOUNT OF WATER SUPPLIED EACH DAY
Balder	*Blackton, Hury*	*About 17 million gallons*
Lune	*Grassholm Selset*	*16 million gallons*

In addition to these reservoirs, water is taken from the River Tees at these points:

INTAKE	QUANTITY – MILLION GALLONS PER DAY	USERS
Low Worsall, near farm	*9*	*Industrial*
Broken Scar, two miles west of Darlington	*15*	*Tees Valley and Cleveland Water Board*
Broken Scar, two miles west of Darlington	*6*	*Darlington Corporation Waterworks*

6 Water-power

WATER-WHEELS

It is a long time since men first looked at the force of rushing water and realised that it could be made to work for them. Usually it was river water that they captured to drive a water-wheel, but we saw in Chapter 3 that at Beaulieu they used the rise and fall of the tide to do it. There have never been many tidal mills in Britain, but there are still a number of water-mills worked by fresh water.

The earliest use of water-power in Britain was for grinding corn. The water turned a great wheel which moved a large stone, and the corn was rubbed into flour as it lay between the moving stone and the one underneath. Later, water turned wheels which drove machinery for spinning or weaving cloth, or for pulling or drawing the hammers of iron works.

At first a paddle-wheel was set up in a swiftly-moving current of water and the force of the water hitting the paddles turned the wheel. Then engineers found that it was possible to use water from a river with a slow current, by diverting the water from the river at a point higher upstream into a narrow channel and letting it fall on to the paddles of the wheel. These wheels were simple to build and worked very efficiently in Britain, where there was nearly always plenty of water in the rivers.

Some of these old water-wheels can still be seen, though not many of them are working now. Are there any in your district? They are very interesting to visit, although the water above and below the mill is usually dangerous. There were two ways of using the water, either from the top of the wheel, when it was called an 'overshot' wheel, or from somewhere between the centre and the

bottom, when it was called a 'breast' wheel. The first wheel was turned by the *weight* of the falling water, the second by the *speed* of the falling water.

If a local wheel is no longer working, perhaps some of the older people in the district will be able to tell you about it, and the date when it stopped work and what job was done inside the mill. Try to make some sketches to show how the mill worked.

Here, to show the power of falling water, are some facts.

A flow of water, 125 gallons per second, falling thirty feet, would develop fifty horse-power – that is, the same amount of power as from five motor engines of ten horse-power each. It was quite possible to get this amount of water and fall on many streams in Britain. Thus you can understand that before the days of steam power, water could do a great deal of work.

At Botley in Hampshire there used to be three water-mills to grind the corn. Today only one stands beside the road, with the water of the River Hamble flowing under its buildings. There are no visible signs of the other two mills now, but their foundations were discovered not long ago when some digging was done near the present mill. This is one of the few old mills still in use, grinding wheat grown in Hampshire. The flour from this mill is known as stone-ground flour, because it is ground by the great millstones that were used in the days when the mill was powered by water. The millpond is still there, and stretching across the valley can be seen the grassy bank which holds back the water until it is taken along the mill-race to the buildings. But the great stones are no longer turned by water; the motive power of all the machinery in the mill is electricity, installed because the mill could not run at a profit unless the machinery moved all the time, and because the water was not always plentiful. The millpond and the water are still used, however, as the fall of water from the pond to the mill generates enough hydro-electricity to work some of the machines. When the river water is low, electricity is taken from the grid system.

Mills were used for purposes other than grinding corn. On the

River Itchen in Hampshire there was a mill which made blocks for the sailing ships at Trafalgar. In the Cotswolds and Yorkshire the water-mills were used in the past to drive the machinery of woollen mills, and in Lancashire for machinery in cotton mills; near Sheffield they drove hammers in the forges. As in the Hampshire corn mills, people found that sometimes there was so little water in the streams that the wheels could not be turned, so instead they used steam power, and later, electricity. If you have a mill on your river, do not assume that it was a corn mill until you have explored it and made inquiries about it.

Why are there so few water-wheels working today? The main reason is that steam has taken their place because it is more powerful, more reliable and enables factories to be set up anywhere. Most water-mills were used for grinding corn grown near villages, but today most of our wheat is imported, so flour comes from a few huge mills near big ports.

Water-wheels today could not develop enough power in one place for modern factories to run economically. Many rivers, however, are still used for power, as their water can be made to generate electricity.

HYDRO-ELECTRICITY

Hydro-electricity is a compound word meaning electricity made by the help of water. The engineer uses water under the pressure of more water and forces it through a narrow opening into a larger space. (You can see this happening when you turn on the tap over the sink quickly, or when you use a garden hose with a nozzle which is narrower than the hose pipe – the narrower the nozzle, the smaller but stronger will be the jet.)

Now look at Fig. 27. A jet of water travelling at high speed strikes the vanes or blades of the wheel of the turbine and makes it go round extremely fast; the shaft of the wheel is connected to an electric generator and, as it goes round, it drives the generator and makes electricity.

(*above*) Barnard Castle
(*below*) The estuary of the River Tees

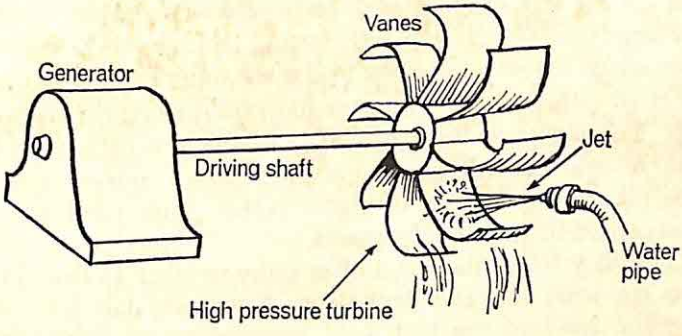


FIG. 27. A turbine in action

The engineer's problem is to obtain a jet of water powerful enough to turn the turbine very quickly. He gets it from a large amount of falling water, which gives a great weight of water to push the vanes.

In Britain there are no very high waterfalls, but this does not matter, as engineers have found that a small amount of water falling continually will do the same job as more water taken from a big waterfall.

POWER DEVELOPMENTS IN NORTHERN SCOTLAND

A large hydro-electric project was carried out on Loch Lomond, north of Glasgow. The generating station is built on the western side of the loch and contains four turbines which can generate 130,000 kilowatts of electricity. There are no waterfalls in this district, and no large rivers which the engineers could use, but every minute a quarter of a million gallons of water are brought 900 feet down the mountain-side in huge pipes. From the sketch map (Fig. 28) you will see how this water has been collected from many tiny streams on the mountains to the west and led into Loch Sloy.

(*above*) The River Avon in flood near Tewkesbury
(*below*) Church Street, Upwey, after flooding

Some of the water comes from streams which did not originally flow into Loch Sloy, but directly into Loch Lomond, or into other rivers which flowed westwards. Today the water from these streams is carried into Loch Sloy by aqueducts built along the mountain-sides. The arrows on the map show you which way the water flows in these aqueducts. There are seven miles of aqueducts, and in some places, where spurs of higher ground intervened, the engineers carried them through tunnels.

Loch Sloy stores the water after rainy weather so that the turbines can work even in a dry season. A concrete dam was built to raise the level of the loch 147 feet. The dam is 160 feet high and 1,160 feet long and from it the great pipe, fifteen feet in diameter, runs eastwards for one and three-quarter miles, carrying the water to the mountainside above the generating station. Here the one great pipe divides into four smaller ones which plunge 900 feet down to the Loch Lomond shore. From the power house, cables carry the electricity to work machines and to light houses in all the surrounding districts as far as Glasgow, forty miles away (see the photograph facing p.81).

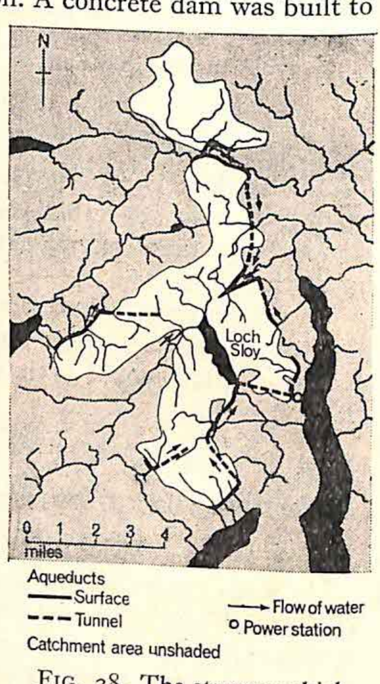


FIG. 28. The streams which supply Loch Sloy

There are now other developments of a similar kind in northern Scotland where there are heavy rainfall, steep slopes, natural lakes for reservoirs, or suitable areas which can be flooded. In 1944, 102 schemes were approved by Parliament of which some are working.

The largest undertakings are as follows:

Tummel-Garry Project in Perthshire;
Loch Sloy, Loch Morar and Lochalsh;
Breadalbane and Lawers in Perthshire, with eight power stations and dams, sixty miles of tunnels and aqueducts;
Glen Affric in Ross and Cromarty, with five dams and four power stations;
Glen Moriston;
Glen Shira in Argyllshire;
Glen Garry;
Loch Shin; Loch Awe; and the Conan Valley in central Ross-shire.

POWER DEVELOPMENT IN SOUTHERN SCOTLAND

In southern Scotland, the Galloway Hydro-Electricity Development centres on the Rivers Doon, Ken and Dee, which flow southwards towards Solway Firth from the western part of the Southern Uplands.

The level of Loch Doon has been raised by building a dam, and eight other dams have been built in the area. There are five power stations, of which the largest is Tongland.

POWER DEVELOPMENT IN ENGLAND AND WALES

Hydro-electric schemes in England and Wales are small compared with those in Scotland. Only 0.25 per cent of the electricity generated in these two countries comes from water-power.

There are many people who do not wish to see this kind of development in mountainous regions, because they think that the generating stations, the pipes and the dams spoil the appearance of very grand scenery. Their argument is that there are now few districts in Britain where really wild country can be seen and that pipes and cables should not be allowed to disfigure these areas,

because they are reminiscent of factories and towns, the very things we may wish to forget on our visits. What is your opinion? Do you think that British mountains should be left wild? Or do you think that power should be obtained from their rivers? This is a good topic for discussion; it has been discussed many times already in Council Offices and Committee Rooms.

7 Transport

NAVIGATION IN THE UPPER REACHES

Those of you who live inland know that it is unusual to see boats carrying goods on our rivers, but that at many places near the towns there are boat-houses where holidaymakers may hire canoes, punts or rowing-boats for pleasure. Such places are worth exploring. The boat-houses may be built on old quays where goods were landed in the past. If you have a boat-house near your home, have a careful look round to see whether there are any signs of a quay. Examine the landing-stage itself to discover whether there are any stone pillars underneath. Look for old iron rings, or old storehouses. You may be lucky and find some evidence to prove that your river was used by cargo-boats and that once there was more navigation on the river than there is today.

Most of our British rivers are now too shallow for cargo boats, but in the past, when boats were smaller and there were not so many goods to be moved, even the middle stretches of the rivers were used. This was in the days of very bad roads and clumsy carts, when transport by land was slow and expensive, and when people often went short of wood to burn because they could not afford to pay for it to be carted from the forests. Tides flowed farther inland and large boats came farther up the rivers on the high tides. When the tide ebbed, boatmen would tie up and wait for the next tide to carry them still farther upstream. When there was no longer a tide to carry them against the current of the river, boats were often pulled by men or horses, or pushed with long poles.

Teams of men would toil along the river banks, pulling the boats by means of ropes, and if the wind were favourable, they

might even raise a sail. On the River Severn, a gang of men was accustomed to wait at the 'Mug House', an inn on Bewdley Quay which was the depot for goods from the Midlands going to Bristol and the West Country. They waited until they were needed to pull a boat over the near-by shallows as it passed upstream to Bridgnorth. If the boat stuck fast on the shallows, the boatmen would cast part of their cargo overboard in an attempt to lighten it. We know that the people of Apperley, a village on the banks of the Severn, used to search the river for coal which had been thrown from boats for this reason.

When vessels could travel no farther upstream, goods were unloaded and at that point a town would grow up. Many British towns which are a long way up the rivers on which they stand were once ports: for example, Norwich, Lincoln, Bawtry, Tewkesbury, York and Chester. If you visit these towns today, you may find proof of this in the street-names near the river, in the name of an inn on the river bank, by finding an old quay, or perhaps by seeing in a wall a hook from which once hung the great metal ring to which ships tied up.

WEIRS

Above the tidal limit a river would sometimes flow through deep pools and sometimes over rapids. To make a stretch of shallows navigable, a weir would be constructed at the lower end in order to raise the level of the water above it and make it deep enough for a boat to pass.

The most common type of weir was made by putting a double line of stakes across the bed of the river, and filling the space between with stones. In the middle were gates which could be opened to let a boat through. Going downstream boats rushed through, but going upstream was more difficult. Men and horses had to haul on ropes to pull the boats against the current. These weirs solved the boatmen's problems, but they were not popular with people living near by as they increased the danger of floods.

Sometimes local landowners, perhaps millers who needed water for their mill-wheels, built solid stone weirs which prevented boats from passing. If the boatmen fought legal battles to get the weirs removed they did not often succeed, as the courts tended to support the local men rather than the boatmen who might live many miles away.

In the Middle Ages solid weirs became such a threat to river navigation that laws were passed to help the boatmen. Edward the Confessor ordered all the weirs on the Thames, Trent, Severn and Yorkshire Ouse to be destroyed; in Magna Carta in 1215 it was stated that weirs on the Thames and the Medway should be removed; an Act passed during the reign of Edward III began: 'Whereas the common passage of boats and ships in the great rivers of England be oftentimes annoyed by the inhancing of mills, weirs, stanks, stakes and kiddles, in the great damage of the people, it is accorded and established that all such things shall be taken out and utterly pulled down without being renewed.' The mill-owners, however, continued to break the law and delay the passage of boats.

Where weirs were used to raise the water for a mill, the millers were expected to let boats pass, but they could charge a toll. They often caused delay in opening the sluice-gates, which annoyed the boatmen who wanted to get on with their journey and who also thought that they should not be charged a toll. Indeed, why should not the millers be charged for using the water?

FLASH LOCKS

After floods had passed down a river, a gravel bank might make a new shallow. If a boat was stuck on it, men would float off the boat by building a temporary dam of brushwood and turf across the river astern of the boat. This would raise the level of the water until the boat was able to clear the shallows. In some places water was held for this purpose in a basin beside the river, but shut off from it by a sluice-gate. When a boat wanted to come over the shallows, the

sluice-gate was opened and the water from the basin rushed out and for a few moments gave enough water to float the boat over. This was called a 'flash' lock. The earliest of these locks was near Alresford in Hampshire, on the River Itchen above Winchester; it was designed by the Bishop of Winchester at the end of the 12th century. An earthen wall was built across a tributary of the River Alre to collect water in the pond until it was needed.

As you explore your river, keep a look-out for weirs and sluices. Try to discover why and when they were built. Make sketches to show how they work and draw a map to show their position on the river. Notice whether the basin behind an old sluice is still a swampy area or a damp meadow.

POUND LOCKS

During the 17th century, a better method of raising boats over shallows was first used in England. This was the 'pound' lock, a watertight chamber between double gates in which a boat could be raised or lowered without too great a loss of water downstream. Pound locks had been used in Italy and France; they were first used in England on the River Thames and in the Fens, and later on canals.

NAVIGATION IN THE 18TH CENTURY

An Englishman, William Gilpin, travelled down the River Wye by boat and in 1782 published an account of his trip. One passage runs:

> 'At Lidbrooke is a large wharf where coals are shipped for Hereford and other places. A road runs along the bank; and horses and carts appear passing to the small vessels which lie against the wharf to receive their burdens.'

Perhaps you know that coal is found in the Forest of Dean, to the east of the River Wye. Hereford is a town farther upstream, so

those vessels carrying coal were going to make their way up against the current with their loads.

At Monmouth, Gilpin reports, 'little boats lay moored, taking in ore, and other commodities, timber, charcoal and stone from the mountains. These vessels, designed plainly for rougher water than they at present encountered, showed up that we approached the sea.' If you look at a map, you will see that Monmouth is far from the sea and above the limit of navigation for cargo boats today.

RIVER NAVIGATION TODAY

In the 19th century, when the roads had been improved and railways built, river navigation declined and has never again become as important as it was in earlier times. There are, however, certain British rivers which are still used for navigation, but the navigable distances are very short when compared with those on rivers like the Rhine and the Yangtse.

ENGLAND

RIVER	LENGTH OF NAVIGABLE STRETCH
	miles
Bristol Avon	$14\frac{1}{2}$
Medway	43
Nene	$91\frac{3}{4}$
Yorkshire Ouse	69
Parret	20
Severn	42
Thames	125
Trent	99
Waveney	25
Weaver	22
Welland	30
Witham	36
Yare	30

SCOTLAND

RIVER	LENGTH OF NAVIGABLE STRETCH
	miles
Clyde	*29*
Forth	*62*
Tay	*29*

On some rivers today you will find work in progress to improve the navigation. On the River Nene, for example, the Catchment Board of the river has ordered work which will allow ships of up to 400 tons to reach Peterborough, and barges drawn by a motor tug have reached Northampton from Peterborough, taking ten days to pass up the river. Perhaps Northampton will once again become known as a river port as it was hundreds of years ago.

Those of you who live near rivers which are or might be navigable may be able to obtain information about similar work by the local River Catchment Board, whose duty it is to develop the river in the best possible way.

CANALS

A great canal builder of the 18th century, James Brindley, said that running water was a giant, but if you built a canal you had laid the giant on his back. He meant that by canalising a rushing river you tamed the force of the water so that it was no longer a danger. The still water of a canal might freeze more quickly than the moving water of a river, but a canal would not flood or dry up because its depth could be controlled. Rivers follow their own natural winding courses, but canals go straight to their goals. No pilots are needed.

In the 18th century, when travel by road and river was still difficult, men thought that the new canals would solve their transport problems. Canal transport was cheap; when the Duke of Bridgwater asked Brindley to cut a canal to take coal from his

coal-mines at Worsley into Manchester (opened 1761), his transport costs were so much reduced that he could sell his coal very cheaply, and he made a fortune from greatly increased sales. Josiah Wedgwood helped to pay for the Trent and Mersey Canal so that he could send away his china goods. They were far safer in barges than in baskets carried on horseback over very rough roads.

Between 1760 and 1840, about 3,600 miles of canals were built in Britain. But when mine and factory owners decided to build a canal, they did not find out if others were being planned near by, so many canals were made to link a single manufacturing or mining area to the nearest navigable river or port. Some of these canals were later joined to others, so that today there are four main cross-country canals – the Trent and Mersey, Kennet and Avon, Leeds and Liverpool, and the Grand Union (formed by the amalgamation of a number of canals from London to Birmingham with the River Trent).

The greatest disadvantage of rivers for transport in any country is that the navigable stretch stops well before the watershed at the source of the river. Thus boats cannot sail from one river to another unless a canal is cut to link them. When industries began to increase, there were goods waiting to be moved from area to area. As roads were so bad, canals were planned to provide transport. But in some cases, for instance Lancashire and Yorkshire, the areas are separated by hilly country, yet canals were made to climb over the hills by means of a staircase of locks, which lifted the boats step by step to the top and let them down gradually to the plain on the other side.

SUPPLY OF WATER

Canals need a constant supply of water in order to avoid shallows, which are such a nuisance to river users. When building canals, engineers have to arrange for the water-level to be maintained, because water is continually being lost by evaporation and by

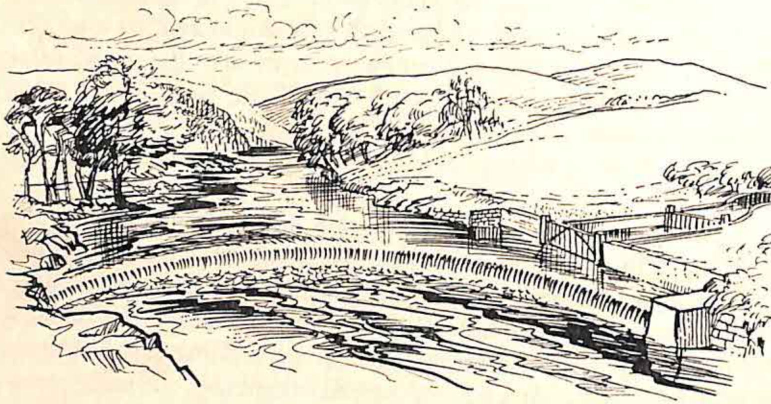


FIG. 29. Water flowing from the River Dee above Llangollen into a 'feeder'

travelling downhill at the locks. Canal water is taken from streams and reservoirs and is diverted into the canals. Fig. 29 shows the water flowing from the River Dee above Llangollen into a 'feeder', which later flows into the Ellesmere Canal. The horseshoe-shaped weir holds up the water to make sure that even when the river is low, some water will flow into the canal. The sluice stops any floating wood or vegetation from flowing into the canal.

When there is no river big enough to supply all the water needed for the canal, engineers have to dam up smaller streams and make a reservoir in which water can be stored in floodtime until it is needed. An example is the Tring Reservoir which supplies the Grand Union Canal. Fig. 30 shows a summit reservoir: the Foulridge Reservoir on the Leeds and Liverpool Canal which supplies water to the canal on both sides of the watershed. At Crofton, the summit level of the Kennet and Avon Canal, water is pumped into the canal. Inside the engine house there is a pair of James Watt condensing beam engines which were made 150 years ago and have been in use ever since.

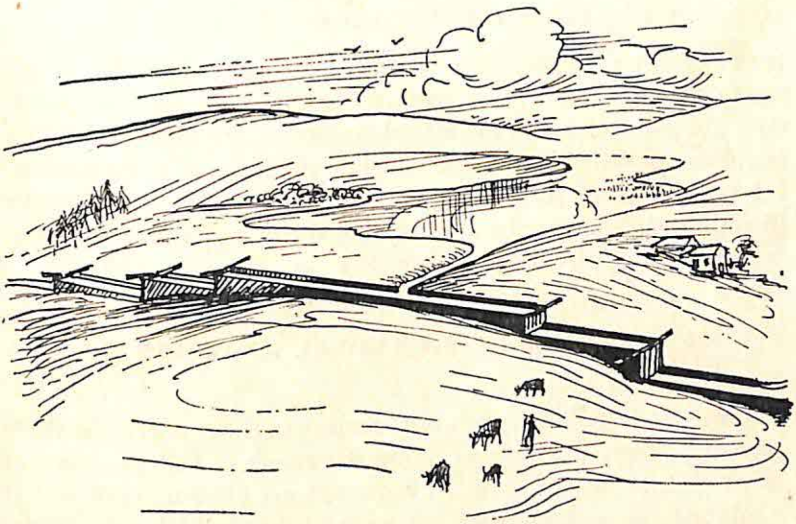


FIG. 30. A summit reservoir

The amount of water in the canal is constantly watched by the engineers. Men called 'lengthmen' live in cottages on the canal bank to keep watch over each section, and they report any unusual signs to the engineers. After heavy rain, or when snow is melting, they may find too much water in the canals and have to open the weirs in their sides to let the surplus flow away; some of these weirs are merely stone or brick walls over which the water flows when it reaches flood-level. Lengthmen continually watch the banks for signs of a break; breaks are more dangerous on a canal than on a river, as canals are sometimes built above the level of the land. If the water breaks out, it rushes down with great force, and does much damage because it flows so quickly. Unlike a river, however, once the first rush of water is over, the flood can be controlled by shutting the nearest lock gates, and not allowing any more water to flow into that section until the break has been mended.

THE CANALS IN YOUR AREA

If you live near a canal, you will have plenty to do carrying out your own discoveries. This section has tried to show how canals took the place of rivers for inland transport, but if you wish you can discover other facts about canals – the locks and the tunnels, the types of boats used and goods carried, the network of canals in your area. You may be interested in the history of canals – who built them and why they were needed.

NAVIGATION IN THE TIDAL REACHES OF A RIVER

You will find small craft on every estuary in the country, for there is always plenty of shipping round the coasts of Britain. Some of these vessels are fishing-boats, but many are pleasure craft and at weekends you will see them sailing out to sea at high tide. In the larger estuaries, where there is deep water at all states of the tide, many large ships come and go, and others are tied up to the wharves or are in the docks along the river bank. A glance at a map will show you that nearly every large port in Britain is situated on a river estuary several miles from the open sea.

Why is this position better than one on the open coast? Perhaps the map of the port of Bristol (Fig. 31) will help you. The water in the estuary is sheltered from the high waves brought by the storms and rarely gets rough. The ships can remain still while they are tied to the quay and will not batter themselves against its sides; therefore loading and unloading will be easier.

By penetrating inland in this way, ships can get closer to the goods they have come to collect, and can take the goods they have brought from other lands nearer to the people who want them. In Britain no place is very far from a port. Many manufacturers prefer to get their goods quickly on to ships because it is cheaper to send goods by water than over land. Long ago, people preferred to keep their ships away from the open sea so that pirates could not

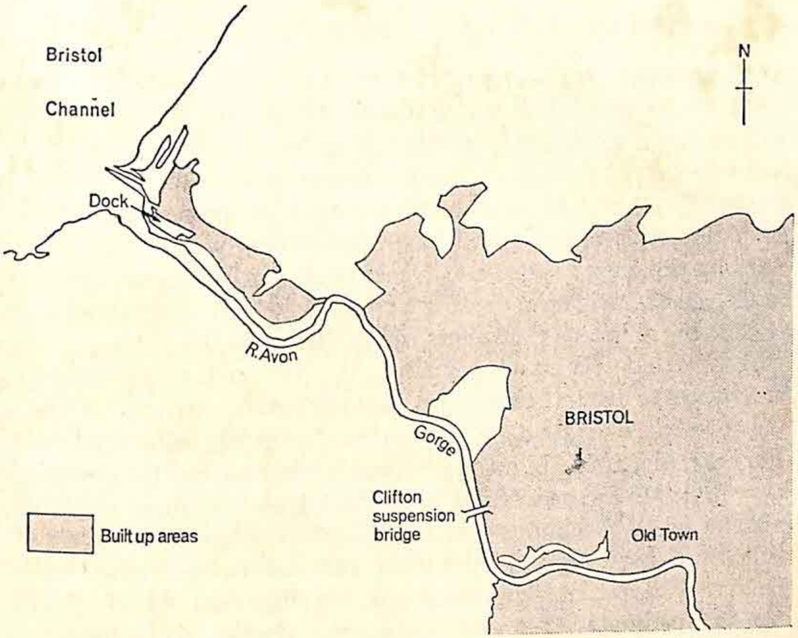


FIG. 31. Bristol and the course of the River Avon

see them or the town and take them by surprise. But the merchants at Bristol have had to build another port at Avonmouth to take the larger modern ships. Two reasons for this are the silting up of the channel to the sea, and the great increase in the size of ocean-going ships.

If the lower reaches of a river are not dredged regularly, the channel will become too shallow for modern big ships because of the mud dropped by the river. When this happens, seagoing trade can no longer reach the old riverside ports. A good example is Chester, once the most important port in north-western England, through which passed all the trade with Ireland. Now it can hold regattas for small boats on the River Dee, but it has lost its harbour for big ships.

MAINTENANCE OF A PORT

At every large port a record is kept of the tides, currents, wave movements, prevailing winds, depth and shape of the channel. Although a river is continually bringing down mud, most of which is dropped in the estuary when the current is checked by the tide, at low tide there is still a channel of water flowing in the centre. At high tide, this channel will have the deepest water and will be used by the larger ships. So, in nearly all British ports, engineers in charge of navigation chart the channels which are deep enough to take big ships, so that pilots can steer the ships safely up them.

As the channels do not remain in the same place, the engineers are always revising their charts to bring them up to date and working to keep a channel deep enough for the vessels using their port. For example, after a big storm in the Humber estuary the engineers may find that the sandbanks have moved, so they must check the placing of all the buoys marking the deep channel. Mud is continually being dropped by a river and also being washed down from the sides of the deep channel as big ships pass. At Southampton, it is estimated that mud causes a rise of about six inches a year on the bed of the deep channel, so every few years this must be scraped out.

There are two ways of keeping a channel deep, by dredging or by building breakwaters.

DREDGING The bucket dredger and its fleet of hopper barges are often to be seen at work in a large port. The hopper barges take the sand and drop it where the currents will carry it away from the land.

Usually both dredgers and hopper-barges need tugs to move them, as their own engines are for working the dredging machinery or for controlling the trap-doors which let the spoil fall into the sea. There are two other types of dredger: the suction dredger which works where the bottom is very soft and sucks up the mud; and the grab dredger, which works in awkward corners of the dock

(*above*) The Severn Bore at Stonebench
(*below*) Meander on the River Wye, north of Chepstow

or quay. If you watch a dredger at work, it will be quite clear which type is being used.

Dredgers may also be seen at work on canals. It would be a costly business to take the mud down the canal and out to sea, so the engineers try to dispose of it near by. On the Manchester Ship Canal, for example, they pump it on to the low-lying land alongside. Thus land reclamation goes on together with canal dredging – the engineers put the mud where they want it to make new lands for farming or factory sites.

Unfortunately a dredger works slowly; it and its barges are expensive to build and need a large team of men to work them. As a result, engineers had to think of an alternative method of dredging channels. They made the tides help them.

BREAKWATERS To make the ebb and flow of the tide dredge or scour the channel of an estuary, engineers build breakwaters on either side of the permanent channel. The breakwaters make a passage for the tide and it sweeps up and down this passage so quickly that it moves and carries away the mud. The tide takes away much more mud than one dredger could move, and once the breakwaters have been built, it does not cost very much to keep them in repair. Lights are put on them to guide shipping across the estuary.

If you live near a port you can find out about navigation in the estuary. Perhaps your local library will have charts of the navigable channels, or you can study your estuary from an Ordnance Survey map. The position of the buoys and lights will tell you a great deal about the deep channel and the shallow areas.

(*above*) Hydro-electricity generating station, Loch Lomond, Scotland
(*below*) Two types of lakes in the Lake District

8 River Crossings

FORDS AND BRIDGES

You may have been for a walk in the country and left all roads and paths behind, then suddenly found your way barred by a river, with no bridge in sight. Hundreds of years ago this was a common happening for travellers, and they had to walk along the river bank until they came to a bridge, or to a place where the river was shallow enough to wade across. Near the source of a river there are places where the river is shallow and its bed is level; here you can walk across if you do not mind getting your feet wet, though sometimes there are stepping stones. Such crossings are called *fords* (see Fig. 32). Some place-names end with this word, showing that in the past they were places where the river could be crossed, for example, Oxford, Bradford.

During the last 700 years, more and more bridges have been built. There are still about 150 mediaeval bridges in Britain (although some have been rebuilt or widened in modern times), and about as many from the 17th and 18th centuries. Over 300 bridges have been declared Ancient Monuments which the local authorities are not allowed to alter and must keep in repair. Some of them have triangular recesses where pedestrians can wait while traffic is passing. Sometimes you will find a modern bridge standing alongside an old one.

Notice as you travel along your river that the bridges do not look alike; they are built of wood, stone, iron, steel or ferroconcrete; they may be fixed or moving bridges. All these facts can be recorded in your log-book. Make a map of the roads and railways which cross your river and then visit each place to inspect the bridge.

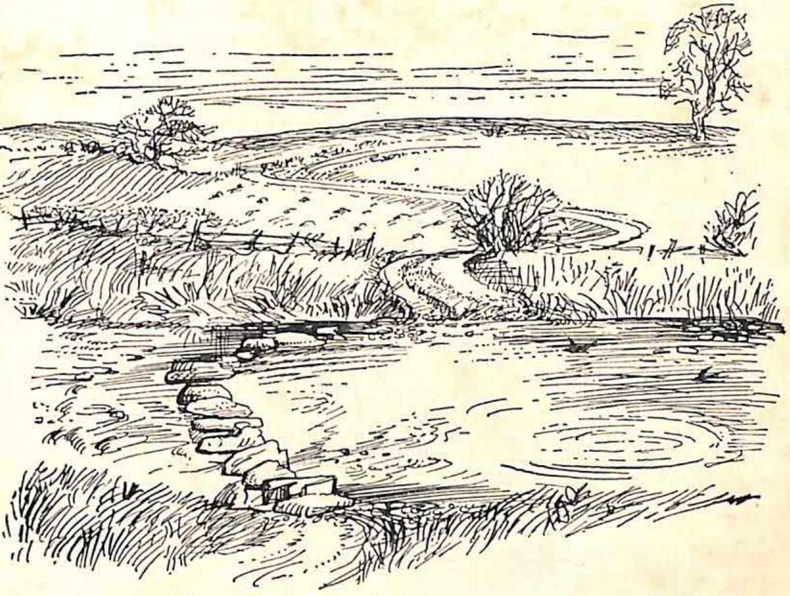


FIG. 32. A ford with stepping stones

FERRIES

There are ferry-boats ready to take you across many British rivers when there is not a bridge near by. Usually the fare is a penny or twopence. Sometimes the ferryman sits in the boat waiting for passengers, but on some ferries where there are not many people wishing to cross, he may be inside his house and you will have to call out 'Ferry ahoy!' The boat may be rowed across, or poled as in the picture (Fig. 33), or there may be a rope across the river by which the ferryman pulls the boat across.

Some ferries are much larger and carry vehicles as well as pedestrians. Fig. 34 shows a diesel ferry which crosses the River Thames at Woolwich, east of London.

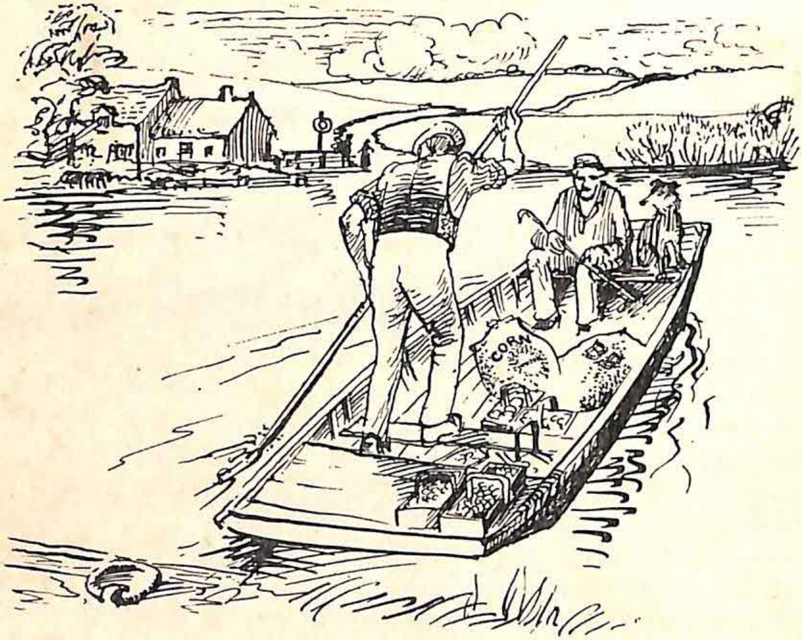


FIG. 33. A ferry

Which are more convenient, bridges or ferries? Why do you find ferries in some places? Look back to the chapter about the River Tees. River estuaries are sometimes too wide for a bridge to be built, or the banks are too soft to hold the heavy supports which carry the bridge. Can you suggest reasons for putting ferries where the river is narrower?

There is no space in this book to tell you the names of the ferries across all the rivers, but try to find out about those near to you and put them on a map for your notebook. The ferries may not work all the year round, so mark them differently to show this. Show how they are worked, and whether the ferryman is ready waiting to carry you across or whether you have to call him. You

can show all this on your map by means of colours or symbols, but remember to put an explanation of the symbols you have used on the map so that other people will be able to understand them.

TUNNELS

If the river is wide, it may be impossible to build a bridge over the river, and so the engineers tunnel underneath. The famous 19th century engineer, Marc Isambard Brunel, was one of the first engineers to complete a tunnel under a river when he designed and supervised the cutting of the tunnel under the River Thames from Wapping to Rotherhithe, 1825–43. This was planned as a road tunnel, but later it was sold to a railway company.

These tunnels are often built only thirty feet or so beneath the bed of the river, and a great amount of water seeps through. The engineer must arrange to have this pumped out while the tunnel is being built and afterwards also. Ventilation is another problem that has to be solved, particularly now that tunnels are used to take roadways under rivers, for the fumes from the exhausts of engines would soon poison the air for cyclists.

One of the most modern tunnels in Britain carries the road from Liverpool to Birkenhead under the estuary of the River Mersey.

RECENT DEVELOPMENTS IN RIVER CROSSINGS

With the great increase in road traffic during the last twenty years, many new roads are being built or improved. When you are out motoring you may be delayed in a traffic jam and very often this is caused by the funnelling of traffic as it approaches a river. In the programmes of road construction, this has been one of the chief problems to be tackled.

The new crossing of the River Thames at Dartford is by a tunnel seven miles long, and the River Mersey Bridge between Runcorn and Widnes is the third largest arch bridge in the world and the largest in Europe; but the two most exciting crossings are the suspension bridges over the Rivers Forth and Severn.

As the spans are so long, a suspension bridge was the only possible choice of design and they are certainly beautiful structures. The cables which carry the roadway are suspended from two high towers and then anchored into the rock on either side. At the time of opening, the Forth and Severn bridges will be the fourth and fifth longest suspension bridges in the world and will look very much alike.

You will remember that in the 19th century, tolls were charged on the turnpike roads. These were gradually freed, as it was considered that roads belonged to everyone and should be paid for from the rates and taxes. However, these new tunnels and bridges have been so expensive to build that the Government has allowed tolls to be charged. It is considered that the new way avoids a long detour, but that it is not essential to use it.

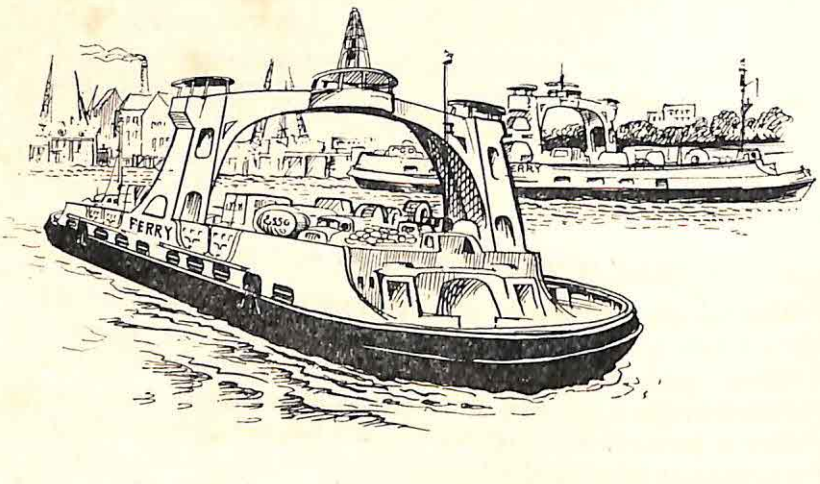


FIG. 34. The diesel ferry which crosses the Thames at Woolwich

9 Valleys as Routeways

In the west coast of Wales there are three seaside resorts, Towyn, Aberdovey and Aberystwyth, and in summer, many visitors from Birmingham and other parts of Britain travel to them by train or road through Shrewsbury. The route the visitors follow can be found on a map of Central Wales. A careful look will show that it does not run in a straight line from Birmingham to the coast, but follows river valleys through the central Welsh mountains which rise to well over 1,000 feet.

Fig. 35 is a large-scale map of part of this route. Near the sources of the rivers the valleys are very steep, so it is quite a feat of engineering to take the road and railway from one river valley over the watershed to the valley on the other side of it. The road can go over the top by the pass, but where the gradient is too steep, the railway must be taken under the watershed by a tunnel.

It is clear then that river valleys make routes for roads and railways through mountainous districts. It is in the upper section of a river's course, the mountain tract, that the route will follow the valley most closely – indeed, this may be the only place where the gradients are easy enough to allow heavily-laden traffic to cross the mountains.

Some of the best examples of river valleys serving as routeways are to be found on the continent of Europe, where for centuries traffic has passed along the banks of the Rhine, the Danube and other big rivers. For examples in more mountainous country you must look at the map of Switzerland, but you will find some on a smaller scale in Scotland and even in England. Here are some for you to look up in your atlas:

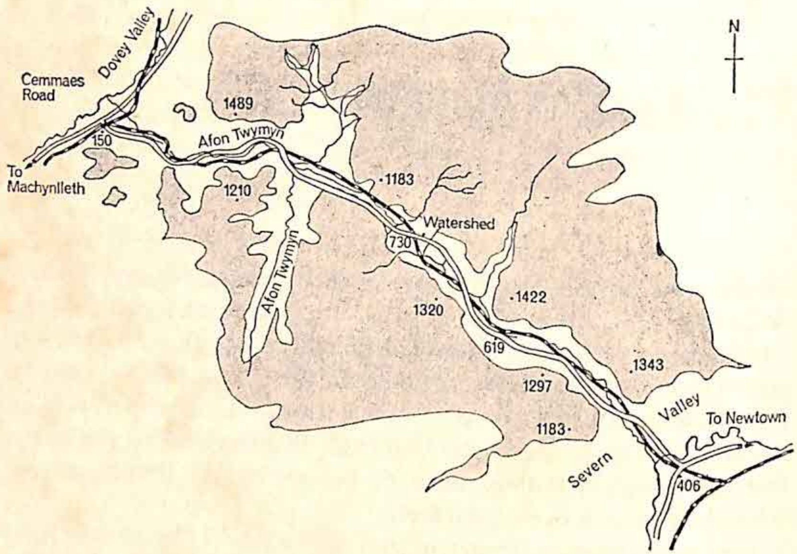


FIG. 35. Part of the route which runs from Shrewsbury to the coas
through river valleys

RIVERS
Avon
Dee
Derwent
Stour (*Kent*)
Test
Thames
Tyne
Wye

ROUTES BETWEEN THESE TOWNS
Bristol to Bath
Llangollen to Bala
Buxton to Derby
Canterbury to Ashford
Southampton to Andover
Reading to Oxford
Newcastle to Carlisle
Monmouth to Chepstow

Where a river flows in its valley tract through low-lying country, roads and railways do not always follow the river bank. In some lowland areas the banks may be marshy and the ground liable to

flooding; to avoid this the routes will run along a little ridge or some distance up the valley side. Look at the map in Fig. 36. Can you account for the varying distances between Lewes and Newhaven?

In a straight line	*$5\frac{3}{4}$ miles*
By river	*$6\frac{3}{4}$ miles*
By railway	*6 miles*
By road	*$7\frac{1}{4}$ miles*

The railway takes almost a straight line between the two places (this is, of course, the shortest way between them). Why is it a mile farther by river and a mile and a half farther by road? The map will help you to answer these questions.

In studying a lowland area, it is a help to make a detailed map showing just where roads and railways go in relation to the river, and to note on it whether the land is marshy, rocky or sloping.

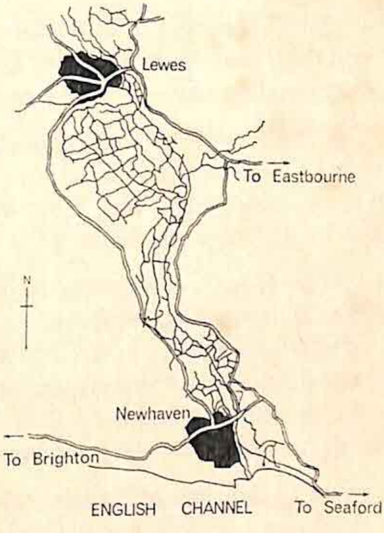


FIG. 36. River valley between Lewes and Newhaven

10 Floods

Unfortunately, there is usually flooding in some river basin at some time during most years, and you may hear broadcast warnings like this:

> 'The Thames is running above its normal height at .... and the Thames Conservancy Board has warned local authorities that flooding may occur if rain follows the thaw.'

The last five months of 1960 had the heaviest rainfall for over a hundred years and floods occurred in many parts of the country. Here are selections from a newspaper report of 8th December 1960,[1] with some supplementary explanations.

> 'The R.A.C. reported last night that although the flood situation continued to improve, 72 roads in 12 counties were still affected; of these 17 were impassable to traffic. The flood level was dropping in Worcester, but at one point there yesterday the Severn reached a level of 16 feet $7\frac{1}{2}$ inches above normal and 8 roads were deep in water.'

In hilly districts of Britain, where many of our rivers rise, an inch of rain may fall on one single wet day. An inch of rain falling over one square mile weighs more than 64,000 tons! Try the sum for yourselves – one cubic foot of water weighs sixty-two and a half pounds.

Many rivers receive water from more than one square mile of country, so in their basins several times 64,000 tons may fall during one very wet day. Not all the rain flows into the rivers; some

[1] Reprinted from the *Guardian*, by kind permission.

evaporates and some soaks into the ground, so it is only after very heavy rain or when snow melts that water in the river rises to danger level. After a spell of fine weather the ground is sometimes too dry to absorb water quickly, and then a sudden storm can make a river flood because all the storm-water runs into it at once.

The newspaper report continued:

> 'Some of the deepest flooding yesterday was on the Nottinghamshire–Lincolnshire border. Parts of the Newark–Worksop and Worksop–Lincoln roads were under 5 feet of water. The River Trent burst its banks in two places in the morning and afternoon and more than two thousand acres were flooded.'

Flooding is a natural occurrence and is regarded as a tragedy only because people have built houses, farms, railways, towns and bridges on the floodplains of rivers. It is easy to build on the floodplain because it is flat, and thus it becomes the most used and richest part of the river basin, so that a flood there can be a disaster.

What is the actual damage from floods? According to the time of year, crops and pastures may be ruined; river banks may be damaged; and there may be boundary problems if the river changes its course; but equally serious is the damage to buildings and stored crops, to fences and ditches, to houses and furniture, and the weakening of the piers of bridges and of river walls.

> 'It was estimated that more than 1,000 sheep and 100 cattle have been lost in the flooded Wye Valley in Herefordshire. Hundreds of poultry and tons of winter feed also disappeared. At Pool Quay near Welshpool, about 260 cattle, 330 sheep, 200 turkeys and thousands of poultry were found dead yesterday as the Severn flooding subsided.'

Before men built on the lowlands, the flood-water from the hills spread out over the plain to a depth of several inches. Some of the water slowly returned to the river and the sea, some evaporated,

some was absorbed by plants and some soaked into the soil. A few trees or bushes might be uprooted, but the plain would be more fertile because a layer of mud would be left behind when the ground dried. This was the way in which the present fertile floodplains were built up. But a flood is not pleasant for the housewife if it happens today.

> 'Mopping-up operations continued at Bath, Cardiff, Shrewsbury, Monmouth, and the Rhondda Valley village of Trehafod. Motorists entered the village for the first time for five days along a road made treacherous by the silt and sludge.
>
> 'Thousands of tons of coal dust, silt and slime have been removed from the main road and houses – but much remains in the side streets. Piled on the side of the road yesterday were furniture, television sets, and clothing ruined by the waters. Some houses, it was feared, might no longer be fit for habitation.'

Look at the photograph facing page 65, showing the floodplain of the River Avon flooded during a very wet season. When a river is full it is not always in flood along the whole length of its course. On many stretches the bed is deep enough to hold the extra water, but a place may be reached where the channel cannot hold as much water. For example, the slope may flatten out suddenly and reduce the flow of the water, or the channel may be silted up with sand or pebbles left from earlier floods, or the river may change direction at a meander, or its bed may become narrower (at a bridge, for example), or more water may come in from a tributary.

It is obvious that we cannot prevent floods as we have no control over the rainfall, snowfall, thawing, slopes, or run-off. However, engineers have found that they can help to some extent to save people from disaster. In the past, they built banks or *levees* to protect the lower land. Fig. 37 shows such an embankment by the River Ken, near New Galloway in south-west Scotland. For many years, these banks may be successful in containing flood-water, but then a larger flood comes and sweeps over the top of the bank.

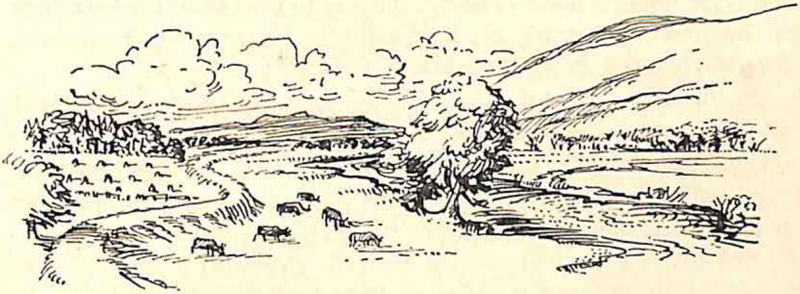


FIG. 37. An embankment by the River Ken in south-west Scotland

It is this very heavy rush of water which does so much damage.

Fig. 38 shows the River Mersey, near Manchester, in flood. At first you cannot say which is the river and which is the flooded land, but the notice board on the left is on the Golf Course and the river bed is on the right-hand side of the picture. In the centre, the top of the dike can be seen, while the other bank of the river is on the extreme right. The dike was not made high enough to keep the flood-water from flowing over the low-lying land on the left.

Keeping the river within dikes may help to cause floods. Mud dropped between the banks gradually raises the level of the bed so that there is less room for flood-water and therefore more likelihood that the river will flood. Today, men try other means of controlling floods. Protection can be gained in two ways: by trying to prevent a flood from starting in the upper part of the valley, or, if that fails and a flood does rush down, by protecting the lower land. The most obvious way to prevent floods would seem to be by deepening the bed of the river, but this is rarely done as it is very expensive and the river mud soon fills it in again. Engineers try to get the water quickly through the flat plains into the sea by taking away obstructions like weirs, solid piers or bridges, fallen trees and decaying vegetation. They also study the movement of the water so that they can warn people living near

the river when a flood is likely. This is to give time for furniture to be moved upstairs, or, if the floods become too menacing, for people to evacuate their houses.

In the upper part of the basin engineers try to prevent a flood or to control it before it reaches the flat plains. They plant trees on mountain slopes, so that the roots can hold back some of the rain-water during a storm. The roots also hold the soil and prevent it from being washed down into the valley.

But the best way to control floods is the most expensive – to build a dam across the valley to hold back the flood-water in a reservoir. Sluice gates then control the amount of water which goes down the river. But it has been found that if a second storm comes quickly after the first and the dam cannot hold the water and breaks, then the sudden double flood is worse than normal river flooding. Thus a second dam has to be built to hold the second flood and this adds to the cost.

FLOODS ON THE RIVER SEVERN

In the Severn Basin floods occur fairly frequently and have been doing so for centuries. In 1484, a great flood was described by Holinshed[1] in these words:

> 'Men were drowned in their beds, houses with the extreme violence were overturned, children were carried about the fields swimming in cradles, beasts were drowned on the hills.'

At the time of another flood, the Severn was called 'Buckingham's Water' as it prevented the Duke of Buckingham from crossing it with the Welsh forces who had risen against Richard III (1483).

The map of the River Severn (Fig. 39) shows you how many tributaries there are on the long course from Plynlimon in central Wales to Gloucester at the head of the Bristol Channel.

It is quite normal for the river to flood after heavy continuous

[1] Holinshed's *Chronicles* as used in Shakespeare's Plays.

FIG. 38. The River Mersey, near Manchester, in flood

rain or a sudden melting of the snow in the Cambrian Mountains. Farmers who own grasslands on the floodplain find that the mud left behind enriches the soil, and would not favour a scheme which completely prevented the floods. However, many of the riverside towns, like Shrewsbury, Worcester and Gloucester, have now built houses on the flat ground which might be threatened by flood-water. The growth of the built-up areas near the rivers has also increased the possibility of flooding, because the water in the street gutters flows into the river and swells the flood-water. Instead of seeping slowly through the ground it adds immediately to the flood.

The flow of the River Severn varies considerably, as these figures giving the flow of water at Bewdley show.

	CUBIC FEET PER SECOND	GALLONS PER DAY
Normal summer flow	*300*	*160,000,000*
Average flow during year	*2,000*	*1,075,000,000*
Flood flow	*23,000*	*11,000,000,000*

The flood flow is therefore more than ten times the normal flow, which may mean a rise of fifteen to twenty feet above the summer level, and water to a depth of ten feet on the floodplain.

Investigations have been carried out into flood prevention and control, but at present it seems unlikely that reservoirs will be built to hold back the flood-water, as this would be too costly. In its upper reaches the Severn has many tributaries, and to make one large reservoir which would be effective would mean building below the Vyrnwy confluence. This would take up a great area of land now used by farmers and for housing. On the other hand, small dams could be built across each of the tributary valleys high up in the mountains where the land is not so valuable. However, to be effective it is estimated that at least twenty dams would be necessary, which would be just as expensive as one large dam.

The Vyrnwy Reservoir is in one of the high valleys of the Severn basin, and you may have wondered why one reservoir could not both store water for the towns and also prevent floods. The table below shows why it cannot serve both purposes.

TYPE OF RESERVOIR	SEASON	REQUIREMENTS
Water supply	*Late winter and early spring*	*Keep full for summer drought*
Flood prevention	*All times, especially late winter*	*Keep empty for flood-water*

It is estimated that for sixteen million pounds two reservoirs could be built which would probably give protection to Shrewsbury but not to the other towns lower down the river.

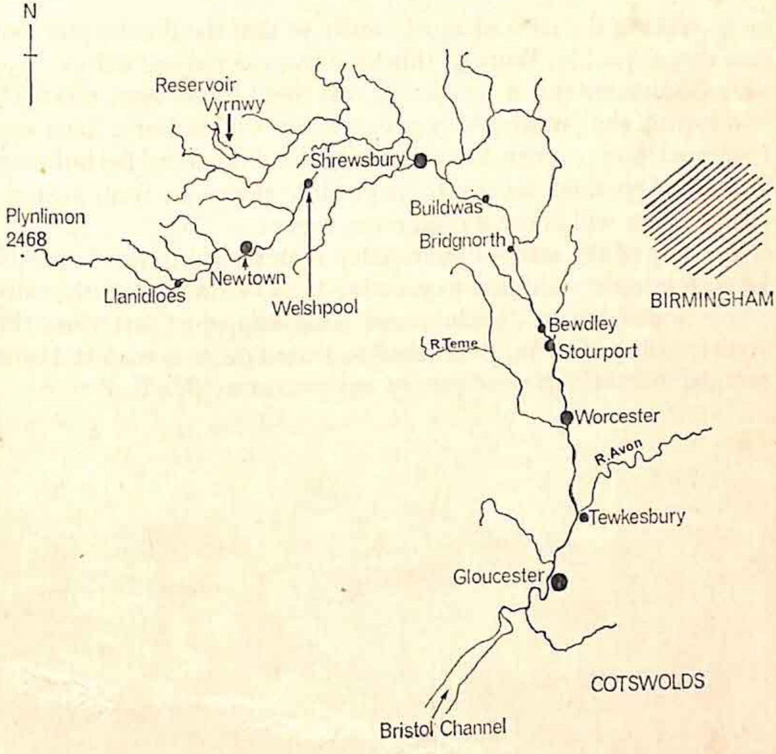


FIG. 39. The course of the River Severn

Above the confluence of the Severn and the Vyrnwy there are embankments on either side of both rivers to protect the farmlands from a possible summer flood when crops are growing. There are similar embankments between Tewkesbury and Gloucester. Severe floods flow over the embankments, but as they usually take place in winter no damage is done; farmers have warning and can move their animals to higher ground before the flood-waters arrive.

Lower down the Severn, towns are trying to avoid flood damage

by improving the river channel locally so that the flood-water can flow down quickly. Work of this kind was carried out before 1939 near Gloucester and it was found that flood levels went down by two feet. A similar scheme is proposed for Shrewsbury. This will cost much more money, but as more flat land is needed for building and therefore more rain-water is put into the rivers from gutters, the problem will become even more urgent.

A study of the state of your valley with regard to floods would be an interesting addition to your log-book. Find out whether any places are liable to flooding, and what happened last time the river overflowed there. Enter the flood areas on your map and note any defences which were put up against future flooding.

11 River Pollution

Water is never 100 per cent pure. Rain gathers impurities as it falls through the atmosphere; the water of a mountain stream may be contaminated by the decaying body of an animal. When water is not pure, we say that it is *polluted*.

Some pollution is not serious. Look carefully at the diagram below.

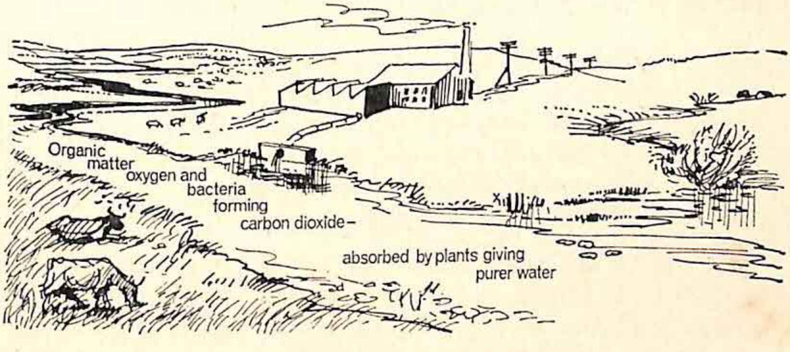


FIG. 40 The purification of river water

The bacteria and oxygen in the river water change the organic matter into carbon dioxide and other useful compounds. Carbon dioxide is used by plants in the river for food and they in their turn give off oxygen; as this happens all the time, the river is kept fresh and pure. The speed at which the purification takes place depends both on the amount of pollution and also on the kind

of river. A swiftly-flowing stream with a broken surface absorbs more oxygen than a slow one, and thus mountain streams are usually very pure. On low-lying land a river flows more slowly and so there is less chance of extra oxygen being present. It is therefore in the lowlands that river water is more often polluted.

Sometimes a river is misused by man. So much poison is introduced into it that no plant or fish can live in the water. What is this poison?

After a heavy shower of rain, water rushes along the gutters and disappears down the drains, probably into the nearest river or stream. Dirt and oil from the roads are washed into the gutters and so water going into the river in this way is not as pure as that coming from the hills. In the 19th century, in Songs from the *Water Babies*, Charles Kingsley wrote lines about the River Mersey which are even more true today:

> Dank and foul, dank and foul
> By the murky town with its murky cowl;
> Foul and dank, foul and dank,
> By wharf and river and slimy bank;
> Darker and darker the further I go,
> Baser and baser the richer I grow.

Factories on the river banks may be rich, but rivers in the industrial parts of Britain have no wild life in them. There are no water-snails, no weed, no may-fly larvae, and thus no fish or birds, for there is nothing on which they can feed. For example, the Severn Fishery Board put large numbers of small trout into the Upper Avon about twenty-five years ago, but many of them were killed by pollution from the sewage works of a town on the banks.

These 'dead' rivers are causing countrymen and nature lovers in the towns much thought. In many districts there are plans afoot to try to bring these rivers back to life by making it illegal for factories or local authorities to pour poisoned water into them. It is no new thing to make laws to keep the rivers pure: in 1372,

there was a law in the City of London forbidding anyone to throw dirty rushes (from their floors), dung, or refuse into the River Thames; and in 1535 Henry VIII passed an Act of Parliament again making it illegal, but nothing seems to have been done, for in the 18th century Dean Swift described the river thus:

'Drown'd puppies, stinking sprats, all drench'd in mud,
Dead cats, and turnip tops, come tumbling down the flood.'

In the past, there were plenty of fish in the rivers which gave people free food; today, trout and salmon are found in only a few rivers and are caught in ever smaller numbers so that they are very expensive, whilst bream and grayling have such a muddy flavour that they are not wanted as food. In the 17th century Isaak Walton wrote a book about fishing called *The Compleat Angler*, in which he described some of the lovely meals to be made with river fish.

It is the anglers of this country who are largely responsible for getting Acts of Parliament passed which safeguard the purity of river water. The latest of these, the River Boards Act of 1948, divided the country into areas, each covering the ground surrounded by the watershed of one big river or group of smaller ones. The rivers of each area are controlled by a River Board whose aim is to make the rivers pure again by forcing all the towns and factories on their banks to treat their waste water before they tip it into the river. This needs expensive machinery and money spent on the upkeep of new sewage and purification plants. Those who agree with the Act say people are no longer allowed to tip the contents of their dustbins on the roads, as they did in the Middle Ages, so why should they be allowed to put dirty water into rivers?

At present River Boards have no control over the tidal waters of their rivers. As a result, many pure streams no longer have salmon in them because the dirty water at the estuary prevents adult salmon from entering when they return from the sea for spawning.

Some pollution may also arise from mining activities. River water is used for washing coal (naturally this makes the water dirty) and it has recently been discovered in Wales that dumps of waste from lead mines contained zinc which poisoned the water and kept the amount of algae and flowering plants so low that no fish could live.

Many towns let the waste water from bathtubs and sinks of houses, hotels, laundries and hospitals run into the rivers. Each town has its own sewage plant which treats the waste water, but it is not always sufficiently purified when it is put back into the river. The use of detergents for cleaning has created another problem, as the foam will not disperse.

When towns were small and scattered, river water became pure again as it flowed from one town to another. As the towns grew in size and as factories were built, no one realised that the rivers needed attention. Water is the most used raw material in factories today; much of it is used for cooling and because it is warm when it returns to the river it injures both plants and fish. Sometimes water is mixed with acids, oils, dyes and even solids, and may be returned to the river without any purification.

At present it is the anglers who are trying to get the rivers cleaner, but this problem of pollution affects each one of us. Our rivers should be pleasant for boating, swimming and picnicking, and should not be foul-smelling or disease-bearing, as they often are at present.

Examine your river from the point of view of pollution. Collect specimens of plants growing in or near it, and note any fish or birds you see there. If it is a living stream you should discover much wild life in and around it. If it is not, try to discover where the pollution comes from. Map the towns, factories and sewage works near it, and add symbols or signs to show what happens to the waste water from each.

12 Interesting Features of Some Rivers

UNDERGROUND RIVERS

You would hardly expect to find rivers flowing hundreds of feet underground where you think there is solid rock, but Fig. 41 shows a stream plunging into a hole on the side of Penyghent in Yorkshire and disappearing underground. Perhaps you have visited the caves at Cheddar in Somerset, or the caverns in Derbyshire, or Peak Cavern at Castleton. At places like these you can go into caves under the hillsides and see rivers flowing along. The

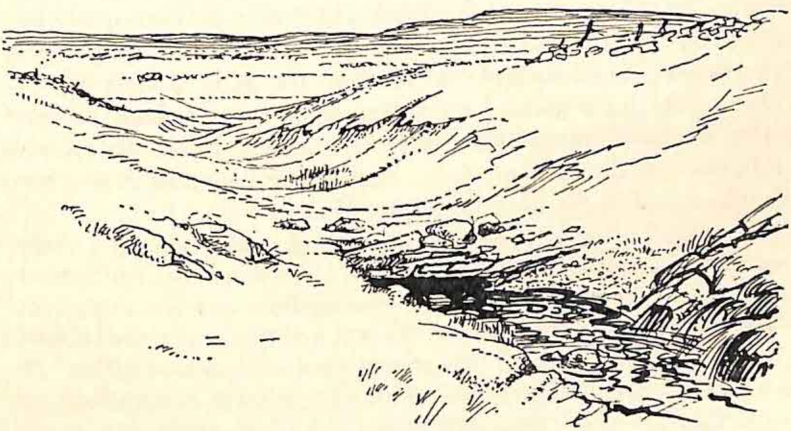


FIG. 41. A stream plunging into a hole on the side of Penyghent in Yorkshire

caves are often wet, with water dripping from cracks in the roof; there may be curious pillars hanging from the roof (*stalactites*, made by drips depositing calcium carbonate), or rising from the floor (*stalagmites*, made by drips from stalactites). When these are artificially lit and reflected in the water of an underground river they look strange and unreal.

The streams may flow for many miles underground, sometimes in large caves. There is one cave in Yorkshire called Gaping Gill which would easily hold a cathedral, for it is 365 feet high. Sometimes streams flow through narrow cracks or channels at great speed and even form lakes and waterfalls. They have tributaries just as ordinary rivers do and when they come above ground they are rivers, like the River Aire when it emerges from the foot of Malham Cove.

Why do some rivers flow underground? There is a chemical reason for this. The rocks in the areas where there are disappearing rivers are composed of limestone, a calcium carbonate ($CaCO_3$), which is soluble in weak acid. Rain-water contains a weak acid, formed by the reaction of the water (H_2O) with the carbon dioxide (CO_2) in the atmosphere, and this can wear away limestone as it passes over it and so form the caves in the hard rock. If you are hunting for underground rivers you must look in those parts of Britain where limestone rocks are found, especially the massive limestone of the carboniferous rocks in the Pennines of northern England and in the Mendip Hills of Somerset.

The underground passages vary a great deal in size and shape: some twist round buttresses of hard, resistant rock; others are beds of rivers which are sometimes shallow and sometimes unexpectedly deep. The speed of the water varies, too, from the stillness of an underground lake to swift torrents or waterfalls.

The proper name for underground explorers is spelaeologists, but they are also called pot-holers. They penetrate many miles through caverns and shine their torches on wonderful rock formations. By means of canoes and by swimming under water they can sometimes follow an underground river out into the sunshine

again. But such activities can be very dangerous if undertaken by those who are not properly trained and equipped, so if you think you would like to become a pot-holer you should join a club and learn how to explore in safety.

BOURNES

In the chalk country of south-eastern England are streams which flow at one time but not at another. These streams are called *bournes*. Like limestone, chalk also contains a great deal of calcium carbonate, but because it is much softer than limestone, caves are rarely found in it. There are fine stretches of chalk country in the North and South Downs, where you will find rounded hills and well-shaped valleys. As the chalk is porous the valleys are usually dry, without any surface water. However, after a very wet season, a stream may appear in these valleys for a short time. In north Kent, there is a valley in which a bourne flowed only every twenty or thirty years. The old people in the village used to call the bourne the 'Woe Water' because they said that it flowed only when trouble was coming to England. It is said that it flowed in 1899 and 1914, the years when the Boer War and the First World War broke out.

You may find evidence of these streams in chalk country by looking for village names ending in -bourne.

RIVER CAPTURE

Did you know that some rivers are pirates? Instead of being content to collect rain-water falling in its own basin, the pirate river cuts a way into a neighbouring river valley and 'captures' some of its water. You will understand this better if you look at Figs. 42 and 43 which show tributaries of the River Dee above Llangollen. Long ago two rivers flowed southwards to the Dee (see Fig. 42), but a tributary of the western one cut into the watershed between them. This new cross-valley was lower and so the water

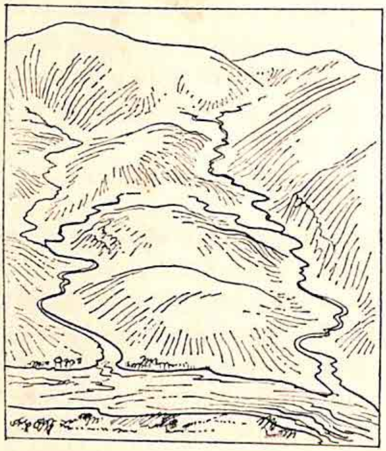


FIG. 42. Tributaries of the River Dee long ago

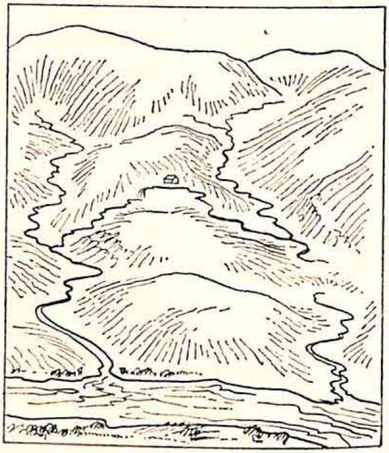


FIG. 43. Tributaries of the River Dee nowadays

from the eastern river began to flow westwards through the cross-valley into the western river. If you visit this place now, you will find that the east–west valley near the point where the cross-river broke through (see Fig. 43) is very narrow and deep. The sharp bend made by the new valley is called the *elbow of capture*. The eastern tributary of the River Dee now has a shorter course. Notice that the part of the captured stream near the elbow now flows north, not south as it did before the capture took place.

REJUVENATED VALLEYS

Sometimes a river gains a fresh start – it becomes young again, or rejuvenated. The causes of this are difficult to explain, but the results can be seen in many places. The photograph facing page 80 shows the beautiful scenery of the valley of the River Wye. This river has continued its winding course by cutting a gorge through the solid rock (which you can see rising as river cliffs almost sheer

from the water). These deeply-cut meanders are said to be *incised*.

Signs of rejuvenation in the plain course of your river may be flat areas, called terraces, along the sides of the valley, a little higher than the present floodplain. These may be noticeable because they are used for farming, or as building sites, being the driest areas in the valley. The map in Fig. 44 shows how the terraces are used in the valley of the River Test, west of Southampton, where they are about fifteen feet above the floodplain on the valley floor. The plain is crossed by many water channels and so is too wet to be used for buildings or roads.

The section across the valley in Fig. 45 shows that these drier areas are the remains of an old floodplain.

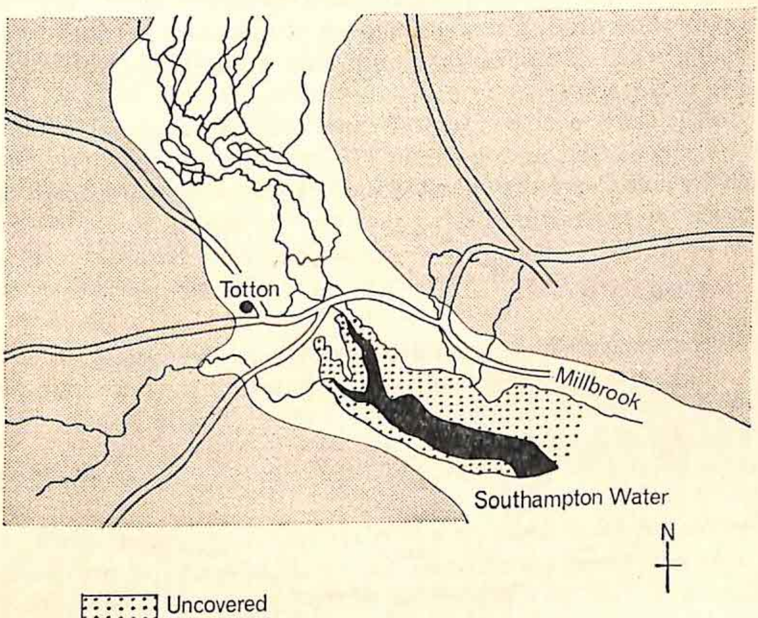


FIG. 44. Terraces in the valley of the River Test

OX-BOW LAKES

On the plain course of some rivers, the flow is so slow that there is hardly any current and the meanders become much more winding, as you can see in Fig. 46a. Sometimes the neck of land between the loops becomes very narrow (Fig. 46b).

When a mass of water comes down in flood-time, in its haste to get to the sea the water will leap across the neck of the meander instead of going round (Fig. 46c). Sometimes, when the flood subsides, the river continues to flow along the shorter channel, and the old meander is blocked off by gravels. The old channel now forms a small lake which because of its shape is called an *ox-bow lake* (Fig. 46d). Sometimes this is called a *mort-lake* from the French *mort* meaning dead. There is a suburb of this name in south-west London where the houses are built on a drained lake which was made in this way.

In the lower course of a river there may be lakes of this kind, or a drained area marking the site of one that used to be there. You may be able to see the old river banks because they are raised or marked by trees or bushes.

BRAIDING

Sometimes rivers have small islands called 'ayots', 'eyots', or 'aits' in southern England, and the stream in which they are found is

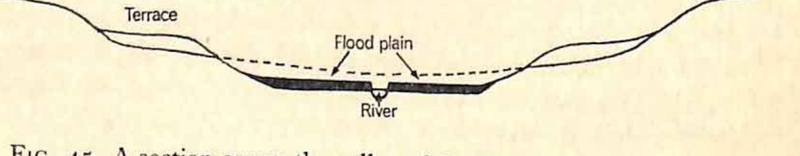


FIG. 45. A section across the valley of the River Test

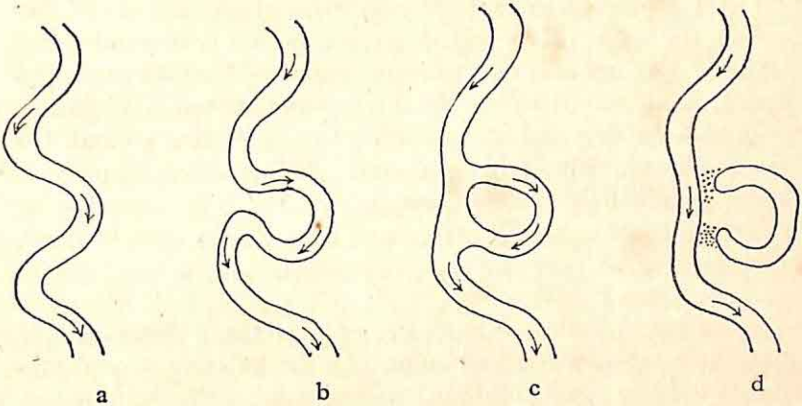


FIG. 46. Stages in the forming of an ox-bow lake

said to be *braided*. The islands are usually built of alluvium or gravel which the river has deposited and some have plants growing on them, making them more permanent. But all these islands are only just above the level of the water at normal times and liable to flooding in winter. Often a braided stream has a fairly straight course. Some people think that you will find either a meandering course or a braided course on the floodplain, but never islets and meanders together. What is the evidence from your river?

DRAINED LOWLAND

The map in Fig. 47 shows a maze of water channels. This is part of the Fen Country in the east of England, where the River Welland and its tributary the Glen flow north-eastwards towards the Wash.

The figures on the map show that this area is just above sea-level, and yet the rivers have still more than fifteen miles to flow before they reach the sea at the Wash, as the inlet is called. You will realise that the water flows very slowly indeed, and a slight rise of river level would flood the area.

Deeping Fen is part of the large district which even to this day we call the Fens. It is a part of England which is very much like Holland and there are protective embankments along the rivers and drains. Eight hundred years ago this was an impassable wilderness of marshland above which rose a few islands of firm ground. On these islands were built the monasteries of Thorney and Crowland, and the cathedrals at Peterborough and Ely. The slow-flowing rivers split into a maze of water channels and, in time of flood, water spread all over the area, covering it with a fine layer of silt.

During the last three hundred years, portions of the marshland have been reclaimed for agriculture by the building of embankments and the digging of drains, for the rivers too have been confined between embankments. As has happened in Holland, men have created a wide stretch of rich farmland from marshes.

THE BORE

A river estuary is the part of the river near the mouth along which the tide flows. Some estuaries become steadily narrower the farther inland they go. In such places the high tide flowing into the river is forced into the narrow space between the banks and therefore the tidal water rises higher. It rushes up the river as a steep, breaking wave, increasing the level of the river by several feet as it passes. This is particularly noticeable on the River Severn, where the wave is known as the Severn *bore*. There is a great difference between high and low tide in the Bristol Channel and the Severn estuary narrows sharply towards Gloucester; it is these two facts which make the bore so large (see the photograph facing p.80). Below Gloucester it may rise to a height of fifteen feet. It continues upstream as far as Tewkesbury Lock although it gradually decreases in height.

You may find that a similar wave has another name on the river you are studying; for example, it is called the 'eagre' on the Rivers

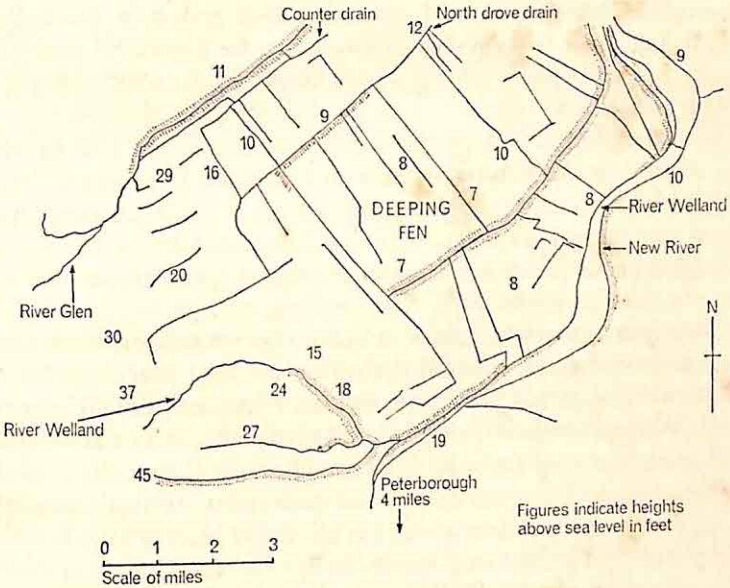


FIG. 47. Deeping Fen and the River Welland and its tributary the Glen

Trent and Humber. Boatmen must look out for this wave when they are on the rivers, for it sometimes comes with great rapidity and strength.

LAKES

A river can never flow uphill.

Perhaps you think this is too simple a fact to print in a book, but men have saved their lives by remembering it. Sometimes, when lost in a mist on a mountain, men have found a stream and followed it down to the houses in a valley, when they might have wandered round the mountain-side and never found anyone to help them.

As a river cannot flow uphill, where it meets a hollow in its course it will not at first be able to run over the mound at the far

side of the hollow. Instead, the water will gather in the hollow and form a huge pond or lake. Only when the surface of the water has risen until it is higher than the mound will the river be able to flow on again.

There are some very large lakes in the world, but British lakes are mainly small. The largest lake in Great Britain, Lough Neagh in Northern Ireland, has an area of 153 square miles. Areas where there are several lakes, such as the Lake District in north-west England, and the Trossachs in Scotland, are famous holiday resorts (see the photograph facing p. 81).

In Britain, most lakes occur in upland areas that were worn away by ice sheets which covered them thousands of years ago. There are two ways in which lakes were formed by ice. Sometimes the rocks themselves were worn away to make hollows in which water collected. Some of these hollows may be near the summits of the mountains, and their water appears dark from the shadows of the grim rock walls which surround them. This kind of lake is called 'tarn' in the Lake District, 'corrie' in Scotland and 'cwm' in Wales. Sometimes they are referred to as 'arm-chair' hollows because they have that shape.

In the larger valleys, the hollows which were scooped out by the ice are now filled with long, narrow lakes, sometimes called *ribbon lakes*. Some of them are very deep. The deepest lake in England, Wast Water in the Lake District, is 258 feet below sea-level in its deepest part. In Scotland, Loch Shiel is 420 feet deep. Some of these lakes have been formed by water collecting behind a ridge of rocks left by a glacier during the Ice Age. These ridges are called *moraines*. The diagrams in Fig. 48 will show you the difference between the two kinds of lake formed by ice-action.

Many of these mountain lakes are slowly filling up with mud. In some places there are now flat, alluvial places where water once stood. Can you suggest where the mud has come from to build up these stretches of flat ground? Perhaps the experiments which you carried out when reading Chapter 2 will help you to answer this question.

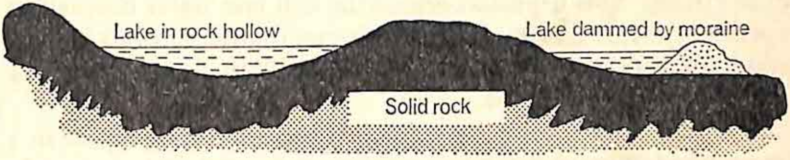


FIG. 48. Two kinds of lakes formed by ice-action

In lowland country, water may gather behind a mound of gravel or beach pebbles – for example, the East Fleet and West Fleet behind Chesil Beach in Dorset, and Looe Pool near Helston in Cornwall. In the most easterly part of England are the Norfolk Broads. These shallow lakes connected by rivers give 200 miles of waterways navigable by yachts and small steamers. They are very popular places for visitors in the summer. It is not certain how these hollows which have filled with water came into being. They may be due to a natural widening of the rivers, or to the blocking up of the water when the river estuaries were cut off from the sea by sandbanks. It is clear that Breydon Water near Great Yarmouth was formed in this way, but many of the smaller Broads lie just off the rivers, separated from them by only narrow stretches of land. Recently a scientist suggested that the Broads are areas from which peat was cut in the Middle Ages and which were later flooded. If this last suggestion is correct, then the Norfolk Broads are not natural lakes but man-made ones like reservoirs.

Another kind of man-made lake, called a *mere*, occurs in Cheshire. You may remember that under part of this county there is salt which man has been mining for many hundreds of years. The rocks above the mines are not very firm and gradually sink into the spaces left by the miners. In this way depressions are formed on the surface and, as the surface rocks are impervious, the depressions fill with water to form large but shallow meres.

A lake which occurs in the course of a river can do certain kinds of work:

1. It takes the river's load of mud from it and lets it flow on as a

clear stream. This happens because the still lake water checks the speed of the fast-flowing river, which cannot then carry its load of mud. Many deposits of mud will gradually fill the lake up, but that will take a very long time.

2. It acts as a regulator for a flood. If there is a sudden rise in a mountain torrent and the torrent flows into a lake, there is only a small rise all around the lake and very little increase in the river which flows from it.

3. It can be used as a reservoir for water storage in water supply and hydro-electricity schemes, for lakes save the expense of building a dam to make an artificial reservoir.

Those of you who are naturalists will find some living creatures and plants in and around a lake which are different from those you would find in a river. The reason for this is that lake water is fairly still. If you are fortunate enough to have a piece of enclosed water near by, it would be interesting to make lists of which plants and animals you find by the river and which by the lake, and compare the two. You will find that the names of some plants and animals appear on both lists, but also that some live only in or by moving water, and others live only in or by still water.

13 More Things to Do

If you live in the country, you need not go far from your home or school before you reach a river. You will have played by it, and probably fished, paddled and bathed in it. Even in the largest town you will be able to find a baby river, called a runnel, on a piece of waste ground, or a trickle in a wide gutter which will help you to understand a larger stream. This book is to help you find out more about rivers and to discover interesting things about the river nearest to your own home. If you wish to know more about one particular aspect of rivers, the table of contents and the index will help you to find what you want. There is not room in this book for all the information you will need, but there will be other books in your local library which should help you.

Because Britain has a heavy rainfall, rivers are part of the landscape and we often see them as we travel about; but because we are always seeing it, we do not think very much about the landscape – we say that we take it for granted. It will be most exciting if you can explore a river near your own home or school. You will need a notebook for your descriptions, maps, sketches and diagrams, and thus you will make a book of your own. It will be more interesting than this book, especially if you put in plenty of illustrations. You may even find pictures in the local paper or postcards in the newsagents.

Perhaps you can collect some specimens of sand or pebbles, and then you will be able to hold an exhibition at the end of your discoveries. Remember that these specimens must have labels either on them or on the box they are kept in. Write down the name of the specimen, the place where it was found, the date when you found it, and anything else you want to say about it.

If you live in a large town you may not be able to walk by a river and do the experiments in the first part of this book. One group of boys in Manchester found that it was impossible to get even a glimpse of the River Irwell near their school, but they were able to draw a plan of the factories and buildings along its banks. Later the boys saw a small river when they went into the country for a day's outing. They knew about rivers by then because they had read about them and knew what experiments they could carry out.

There is no space in this book to tell you about the plants and animals which you will be able to see by the river, but your library should have books to help you. Whenever you are by the water, keep your eyes open. Remember that if you wish to see birds and animals you must be quiet and move gently or you will frighten them away. Remember, too, that your shadow falling on the water will scare the fish. Trees and flowers are easier to observe.

When you see something new, observe it carefully and then jot a complete description down in your notebook. Later you can check this with other descriptions in the library and identify your 'find'. If you study living things in detail and have a book about them you will find that they all have Latin names as well as their English ones. The Latin name is made up of two and sometimes three or more Latin words; the first one is the order or family name and the others the genus, the species and the variety. These Latin names are used in every country; this makes it possible for biologists to know the object even if its local name is different. Local names vary a great deal; even in Britain you will not find the same English name given to the same flower – for example, marsh marigold is known as kingcup in some places.

Now, what about the uses of your river? It is obvious, when you come to think about it, that a river is very powerful and can do a great deal of damage. It can also be a help to man, and there are many uses to which it can be put. It is also obvious that some men

will want to use a river one way and some another, so it is quite a problem to decide how it should be used.

Look again at pages 12 and 13 and find out how rivers are used in Britain. Now, in what ways is *your* river used? Are there any reservoirs, canals, or water-mills? If you live near the mouth, find out whether it is used for shipping. What kind of boats come to it? What do they carry? Where do they come from?

Each one of these questions could be the heading of a page of your notebook. Beneath it, you could set down all you can find out about your river; also the answers to the questions in the next paragraphs.

How do people cross your river? Can you visit the ferries, weirs and bridges, and sketch them? When were the bridges built? What are they made of? Sometimes you can find interesting inscriptions carved on a stone let into a bridge telling you all about the building and opening of it. Copy these into your notebook. Find out more about the people mentioned.

What uses are made of the valley formed by your river? Is it used for roads and railways? What can you find out about the wild life near your river?

14 Glossary

Here are the meanings of some of the technical terms used in this book. They are arranged in alphabetical order as in a dictionary.

AQUEDUCT An artificial channel for carrying water.
BASIN A tract of country drained by a river and its tributaries.
BORE A tidal wave which rushes up a narrowing river estuary.
BREAKWATER A wall of stone or wood to break the force of a wave.
CAUSEWAY A raised road across a wet place.
COMPENSATION WATER The water given back to a river by the waterworks.
CONFLUENCE The place where two or more streams join.
CULVERT A channel for carrying water.
CURRENT Water moving in a definite direction.
DAM A barrier to hold back water.
DOCK A hollow containing water in which ships may be unloaded, loaded, or repaired.
DREDGE To clean out the bed of a harbour or river.
DYNAMO A machine for producing electricity.
ESTUARY The tidal mouth of a large river.
FILTER To take solid impurities from water.
FLATS Low-lying ground, a marshy plain.
FORD A shallow place where a river may be crossed by wading.
GENERATOR Apparatus for producing electricity.
GORGE A narrow valley between hills, often rocky.
GRADIENT The amount of slope, as on a hillside, river-bed, or road.

GULF A portion of the sea, enclosed by land, having a narrower mouth than a bay.

GULLY A narrow channel worn by water on a hillside.

HYDRO-ELECTRIC POWER Energy obtained by the force of falling water.

LOAD Solid material carried by a river.

LOCH Lake in Scotland.

LOCK Section of a canal fitted with sluice-gates to alter the level of water so that boats can be raised or lowered. Locks occur where the level of the ground changes.

MEANDERS Windings of a river.

NAVIGATION, INLAND Communication by rivers and canals.

PASS A narrow way through mountains.

PIER A breakwater, or a pillar which supports the span of a bridge.

POLLUTION Dirtiness (of water).

PORT A harbour with docks, wharves, cranes, warehouses, for unloading and loading ships.

POUND LOCK A lock with two gates.

QUAY A landing space, built into the water, for unloading ships.

RESERVOIR An artificial or natural lake in which a large quantity of water can be stored.

SCREE A layer of stones lying on a steep mountain slope.

SEWAGE Matter carried by sewers.

SILT A deposit laid down by a river which is finer than sand and coarser than clay.

SLIPWAY A place for landing or building ships.

SLUICE-GATE A gate which can be moved to control the flow of water.

SOURCE The beginning of a river.

SPRING The point where a river rises.

SUMMIT Highest point.

TIDE The daily ebb (sinking) and flow (rising) of water, especially of the sea, caused by the moon.

TRIBUTARY A river which flows into a larger river.

TURBINE A wheel turned by steam or flowing water.

VALLEY Low ground lying between hills and usually containing a river.

VALVE TOWER A small building inside a reservoir in which are placed instruments for measuring the level of the water.

WATERSHED High ground separating river valleys, so called because water falling on this high ground drains away from it into the valleys on either side.

WEIR Dam across a river to raise the level of water behind it.

WHARF A landing-stage beside which a ship may be loaded or unloaded.

15 For Further Reading

Books

Rivers of Adventure, Ray Bethers (Constable)
Lorna Doone, R. D. Blackmore (Everyman)
Sick Heart River, John Buchan (Hodder and Stoughton)
John Halifax, Gentleman, H. Craik (Collins)
Inland Waterways of Great Britain and Northern Ireland, Lewis A. Edwards (Imray, Laurie, Norie and Wilson)
The Mill on the Floss, George Eliot (Everyman)
Sweet Thames Run Softly, Robert Gibbings (Guild Books)
The Wind in the Willows, Kenneth Grahame (Methuen)
Wintercut, Elizabeth Grove (Cape)
The Water Gipsies, A. P. Herbert (Penguin)
Three Men in a Boat, J. K. Jerome (Penguin)
Ancient Bridges, Edwyn Jervoise (Architectural Press)
London's River, Eric de Maré (Bodley Head)
London's Riverside, Eric de Maré (Reinhardt)
Time on the Thames, Eric de Maré (Architectural Press)
How Britain's Waterways are Used, John Merrett (Routledge)
Canals, Geoffrey Middleton (Bodley Head)
The White Nile, Alan Moorehead (Hamish Hamilton)
The Blue Nile, Alan Moorehead (Hamish Hamilton)
The Big Six, Arthur Ransome (Cape)
Swallows and Amazons, Arthur Ransome (Cape)
Narrow Boat, L. T. C. Rolt (Eyre and Spottiswoode)
The Adventures of Tom Sawyer, Mark Twain (Dent)
King of the Golden River, John Ruskin (Macmillan)
The Compleat Angler, Isaak Walton (Everyman)

Tarka the Otter, H. Williamson (Longmans)
Three Rivers of France, Freda White (Faber)

Poems – In the collected works of the poets and many anthologies.
'The Stream's Song', Lascelles Abercrombie
'Inversnaid', Gerard Manley Hopkins
'Arethusa', Shelley
'The Cataract at Lodore', Robert Southey
'The Brook', Alfred Lord Tennyson

Notes on the Photographs

Frontispiece – The Afon Tai-Hirion, a swift-flowing mountain stream in the wild Merionethshire countryside, near Arenig Fawr (2,800 ft.) west of Bala, Wales.

Facing p. 14 (*above*) – The River Teviot, Roxburghshire, Scotland. The water is flowing towards Hawick. Notice the banks of pebbles which would be covered when the river is full after rain (see p. 41).

(*below*) – A mountain spring in Yorkshire. The water comes to the surface in the foreground and then flows down to join the River Ribble (see p. 17).

Facing p. 15 (*above*) – Beaulieu River, looking north-west from the Solent. The mouth of the river is further to the right, as at high tide the sea flows over the spit in the foreground. Notice the salt marshes and follow the winding course of the estuary inland towards the top left. In the top right is part of Southampton Water (see p. 32).

(*below*) – High Force, near Middleton-in-Teesdale. Notice the vertically jointed dolerite and the horizontally bedded carboniferous limestone. The water falling into the pool is setting up little waves which are beating against the over-hanging rocks (see p. 38).

Facing p. 64 (*above*) – Barnard Castle. A view across the River Tees with the bridge and old part of the town (see p. 42).

(*below*) – The estuary of the River Tees. In the foreground is Middlesbrough with the Transporter Bridge to the right. Above

the bridge, notice the River Tees again between the breakwaters, and beyond them the wide estuary with Seal Sands to the left and Bran Sands to the right. Near the top of the photograph, Redcar Jetty runs down from South Gare Breakwater with Tees Bay and a bank of cloud above (see p. 45 and 47).

Facing p. 65 (*above*) – Looking down the flooded Avon towards Tewkesbury where it flows into the Severn (see p. 92).
(*below*) – Church Street, Upwey, between Dorchester and Weymouth after flooding following two cloudbursts in twenty-four hours, when over seven inches of rain fell. The villagers are washing mud from their furniture, carpets and blankets (see p. 92).

Facing p. 80 (*above*) – The Severn Bore at Stonebench, four miles from Gloucester. This is the favourite vantage point for viewing the Severn Bore (see p. 80).
(*below*) – Meander on the River Wye, north of Chepstow. This view from Wintour's Leap near Tidenham, Gloucestershire, shows the steep wooded sides of the incised meander (see p. 106). Notice that the river is tidal here.

Facing p. 81. (*above*) – Hydro-electricity generating station, Loch Lomond, Scotland. Notice the four large pipes which bring the water to the power house, and the pylons and cables carrying the electricity to Glasgow (see p. 66).
(*below*) – Lake District. This view looking west shows two types of lakes. In the foreground are two pieces of water which form the head of Hawes Water. This is one of the long narrow ribbon lakes found in the main valleys of the Lake District. Notice near the middle of the photograph a small round lake in a hollow. This is Blea Water, a corrie (see p. 112).

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